A MANUAL

OF

PRACTICAL HYGIENE.

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OF

PRACTICAL HYGIENE

PREPARED ESPECIALLY FOR USE
IN THE MEDICAL SERVICE OF THE ARMY.

BY

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TO

The Memory

OF

SIDNEY LORD HERBERT OF LEA,

THIS IMPERFECT ATTEMPT

TO AID IN CARRYING OUT ONE OF HIS PLANS

FOR

THE BENEFIT OF THE BRITISH SOLDIER

IS DEDICATED.

PREFACE TO THE THIRD EDITION.

THE subject of Hygiene has received so many additions during the last three years that, in order not to enlarge the book, I have been obliged to recast, and indeed to rewrite, many of the chapters. I hope it will be found that no important matter has been omitted. I have changed some of the woodcuts, and have added another plate of the common microscopic objects in water, so that the sediments of surface, river, and well waters are now represented. As before, I have to thank my friend Dr Maddox for his kindness and great care in drawing and naming these objects.

I have thought it advisable to use the chemical nomenclature, notation, and atomic weights now in common use, but I have been careful to introduce no difficulty for those who have been accustomed to the older methods, and in several cases when popular use has given currency to certain terms I have thought it best to keep to the old ways. For example, I have spoken of carbonic acid (CO_2) instead of carbonic anhydride or carbon dioxide, and of sulphuretted hydrogen instead of hydrogen sulphide, and similarly in some other cases; the reason for this in a work of this kind will be readily understood.

April 1869.

PREFACE TO THE FIRST EDITION.

THE Royal Commission appointed in 1857 to inquire into the sanitary condition of the army in England, prepared a new edition of the "Queen's Hospital Regulations," which was published by authority in 1859.*

The new Regulations entirely altered the position of the Army Medical Officer. Previously the Army Surgeon had been intrusted officially merely with the care of the sick, though he had naturally been frequently consulted on the preservation of health and the prevention of disease. But the Regulations of 1859 gave him an official position in this direction, as he is ordered "to advise commanding officers in all matters affecting the health of troops, whether as regards garrisons, stations, camps, and barracks, or diet, clothing, drill, duties, or exercises" (p. 7).

The Commission also recommended that, to enable the Army Surgeon to do this efficiently, an Army Medical School should be established, in which the "specialties of military medicine, surgery, hygiene, and sanitary science" might be taught to the young medical officers entering the army.

This work is an attempt to carry out the wishes of the Commissioners as regards sanitary science, by providing a text-book of Hygiene, illustrated by examples drawn from army life, for the gentlemen attending the Army Medical School.

The Official Medical Regulations have been taken as the basis of the work. I have endeavoured to see what the Regulations demand from the medical officers of the army, and what are the duties they chiefly have to do, and then to explain how the Regulations are to be carried out. In writing this work I have had to deal only with

* "Regulations for the Duties of Inspectors-General and Deputy-Inspectors-General, and for the Duties of Staff and Regimental Medical Officers, &c.," 1859. This work is also termed, for shortness, "Medical Regulations."

one sex, a certain age, and a particular trade; but as the general principles of hygiene are tolerably fully discussed, I have thought it entitled to be called a work on general hygiene.

The work is divided into two Books; in the First I have arranged the chief subjects of hygiene in what is, for my purpose, the most convenient order, and have illustrated them by examples drawn from army life. I have also included some other topics, such as meteorology and statistics, which it is important medical officers should learn. In these several chapters I have thought constantly on what would be useful to army surgeons, who are often far from all books, or possibility of reference. So that, in some parts, I have endeavoured to make the book one of reference, though I have been obliged to compress it to the greatest degree. In the Second Book, the service of the soldier is more particularly described.

To enable medical officers to perform the chemical processes required in the analyses of water and air, and in the examination of food, the Director-General has recommended, and Lord de Grey has been pleased to sanction, the issue of a small box, containing sufficient apparatus and reagents for these processes, and this will be issued to the several stations on demand. After much consideration, I have adopted the French weights and measures, as being more convenient for volumetric analyses, of which considerable use is made. In chemistry the battle of the standards is over, and the simplicity of the French weights is such that even those who are not at first acquainted with them will, in a very short time, find no difficulty in using them. I have made the chemical directions as simple as possible, and have thought it best to use the old equivalents and notation.

I have to thank my friend, Dr Maddox, for very kindly drawing for me all but two of the microscopic objects; his drawings have been very carefully engraved on copper or wood by Mr Bagg. I must express my obligations to the Council of the Royal United Service Institution for permitting me to use the stone with the lithographs of knapsacks, employed in illustration of Dr Maclean's paper, published in the 10th volume of the Journal of the Council.

I have to thank also my friends, Dr Sutherland and Dr Francois de Chaumont, for many valuable suggestions.

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CORRECTIONS AND ADDITIONS.

Page 34, line 22—*for* "ferric sulphate," *read* "ferrous sulphate."

Page 39, line 20—*instead of* "·0017 milligrammes of oxygen," *read* "·0017 grammes, or 1·7 milligrammes of oxygen."

Page 39, eleventh line from bottom—*after the words* "are tested," *insert* "at a temperature of 140° Fahr. and in presence of acid."

Pages 112 and 448—In respect of the outbreak of dysentery produced by sewage irrigation, and recorded by Dr Clouston, it is important to note that the same cause has lately produced, to all appearance, a return of the disease. (*See* "Medical Times and Gazette," April 17, 1869, p. 414.) For two years the sewage had been run into a small stream, and the asylum had been free from dysentery or diarrhœa. But two months after the sewage had been again applied to the land dysentery reappeared, even though the application had been properly made, and carbolic acid had been used as a disinfectant. This matter is one of such extreme moment that every attention should be directed to it.

Page 150—Formula for segment of circle.—*Instead of* "$(Ch \times H \div \frac{2}{3})$, *read* $(Ch \times H \times \frac{2}{3})$."

Page 152—Mr Casella, of Hatton Garden, has lately still further improved his air-meter, and has made it much more sensitive, and capable of registering very great movements of air, as well as currents moving less than 1 foot per second.

Page 176—Food of the Prussian soldier, sixth line from bottom—*instead of* "also pays a mess contribution," *read* "also receives a mess contribution." In addition to what is said of the Prussian soldier's food, it should be noted that it has been lately ordered that in time of war he shall receive, besides having the usual amount of bread, $\frac{3}{4}$ ℔ of meat, fresh or salt, or $\frac{1}{2}$ ℔ of smoked meat, or $\frac{1}{3}$ ℔ of fat bacon (*speck*), 4·4 oz. of rice, or the same quantity of barley; or double the quantity of succulent vegetables, or 3 ℔ of potatoes. He also receives $\frac{9}{10}$ oz. of roasted coffee, increased to $1\frac{1}{2}$ oz. in an enemy's country, and $\frac{9}{10}$ oz. of salt. The vegetables can be increased; and wine (1 pint), beer (2 pints), butter ($1\frac{1}{2}$ oz.), tobacco ($1\frac{1}{2}$ oz.), may be issued in certain cases. Under any great exertions a little spirits may be issued. The Prussian soldier has therefore three rations,—the lowest for time of peace, the higher for garrisons and manœuvres, and the war ration.

Page 344, line 10—*for* "impermiable," *read* "impermeable."

INTRODUCTION.

HYGIENE is the art of preserving health; that is, of obtaining the most perfect action of body and mind during as long a period as is consistent with the laws of life. In other words, it aims at rendering growth more perfect, decay less rapid, life more vigorous, death more remote.

This art has been practised from the earliest times. Before Hippocrates there were treatises on hygiene, which that great master evidently embodied in his incomparable works. It was then based on what we should now call empirical rules—viz., simply on observations of what seemed good or bad for health. Very early, indeed, the effects of diet and of exercise were carefully noticed, and were considered the basis of hygiene.* Hippocrates, indeed, appears to have had a clear conception of the relation between the amount of food taken and of the mechanical force produced by it; at least, he is extremely careful in pointing out that there must be an exact balance between food and exercise, and that disease results from excess either way.

The effects on health of different kinds of air, of water, and to some extent of soils, were also considered at a very early date; though naturally the ignorance of chemistry prevented any great advance in this direction. Hippocrates summed up the existing knowledge of his time on the six articles, which in after-days received the absurd name of the "Non-naturals."† The six articles whose regulation was considered indispensably necessary to the life of man, were—air, aliment, exercise, and rest, sleep and wakefulness, repletion and evacuation, the passions and affections of the mind.

With the exception of the attempts of the alchemists, and of the chemical physicians, to discover some agent or drug which might increase or strengthen the principle of life,‡ the practice of hygiene remained within the same limits

* Herodicus, one of the preceptors of Hippocrates, was the first to introduce medicinal gymnastics for the improvement of health and the cure of disease; though gymnastics in training for war had been used long before. Plutarch says of him, that labouring under a decay which he knew could not be perfectly cured, he was the first who blended the gymnastic art with physic, in such a manner as protracted to old age his own life, and the lives of others afflicted with the same disease. He was censured by Plato for keeping alive persons with crazy constitutions.—*Mackenzie on Health.*

† This title originated in a sentence of Galen, and was introduced into use by the jargon of the Peripatetic school. It was employed in all treatises on hygiene for probably nearly 1500 years.

‡ It was when chemistry was being rudely studied by the alchemists that an entirely different

until physiology (the knowledge of the laws of life) began to be studied. Hygiene then began to acquire a scientific basis. Still retaining its empirical foundation, drawn from observation, it has now commenced to apply the physiological discoveries to the improvement of health, and to test the value of its own rules by this new light. It is now gradually becoming an art based on the science of physiology, with whose progress its future is identified.

But the art of hygiene has at present still another object. If we had a perfect knowledge of the laws of life, and could practically apply this knowledge in a perfect system of hygienic rules, disease would be impossible. But at present disease exists in a thousand forms, and the human race languishes, and at times almost perishes, under the grievous yoke. The study of the cause of disease is strictly a part of physiology,* but it can only be carried out by the practical physician, since an accurate identification of the diseases is the first necessary step in the investigation of causes.

The causes being investigated, the art of hygiene then comes in to form rules which may prevent the causes or render the frame more fitted to bear them; and as in the former case it was the exponent of physiology, in this case it becomes the servant of the pathologist.

Taking the word hygiene in the largest sense, it signifies rules for perfect culture of mind and body. It is impossible to dissociate the two. The body is affected by every mental and moral action; the mind is profoundly influenced by bodily conditions. For a perfect system of hygiene we must combine the knowledge of the physician, the schoolmaster, and the priest, and must train the body, the intellect, and the moral soul in a perfect and balanced order. Then, if our knowledge were exact, and our means of application adequate, we should see the human being in his perfect beauty, as Providence, perhaps, intended him to be; in the harmonious proportions and complete balance of all parts, in which he came out of his Maker's hands, in whose divine image, we are told, he was in the beginning made.

But is such a system possible?

---

school of hygiene arose. The discovery of chemical agents, and the great effect they produce on the body, led to the notion that they could in some way aid the forces of life, and insure a prolonged, if not an eternal youth, and a life of ages, instead of one of years. This belief, the natural result of the discovery of new powers, has not yet entirely died out; and while there are some who still look to every fresh agent as possibly containing "the balsam of life," there are also still enthusiasts who search the mystic tomes of the alchemists or the Rosicrucians, in the faith that, after all, the great secret was really found. It may be worth while to consider the idea which underlaid the dreams of the alchemists. Life was looked on as an entity or principle, liable to constant waste, and to eventual expenditure. If some agent could be found to arrest the waste, to crystallise, as it were, the tissues in their full growth and vigour, decay, it was conceived, would be impossible, and youth would be eternal. In other cases, it was supposed that the agent would itself contain the principle of life, and therefore would at once restore destroyed health, and recall again departed youth. We now know this idea to be wrong in every point. The constant decay the alchemists sought to check is life itself, for life is but incessant change, and what we call decay is only a metamorphosis of force. To arrest the changes in the body for one single moment would be death, or, short of death, it would be lessening of the forces which are the expression of life. Nor is there any hope that the extension of the period of vital force can ever be accomplished except by improving the nutrition of the tissues. Here, indeed, it is just possible that, in time to come, drugs will aid Hygiene, either by better preparing food for the purposes of nutrition, or by removing or preventing those chemical changes in the tissues which we call decay. But at present, certainly, no rules can be laid down for the use of drugs in hygiene, except in that debateable land which lies between hygiene and the practice of medicine, that is, in that uncertain region which we do not like to call disease, and yet which is not health.

* Physiology and pathology are, in fact, one; normal and abnormal life, regular and irregular

Is there, or will there ever be, such an art, or is the belief that there will be, one of those dreams which breathe a blind hope into us, a hope born only of our longings, and destined to die of our experience? And, indeed, when we look around us and consider the condition of the world—the abundance of life, its appalling waste; the wonderful contrivances of the animal kingdom, the apparent indifference with which they are trampled under foot; the divine gift of mind, its awful perversion and alienations; and when, especially, we note the condition of the human race, and consider what it apparently might be, and what it is; its marvellous endowments and lofty powers; its terrible sufferings and abasement; its capacity for happiness, and its cup of sorrow; the heavenly boon of glowing health, and the thousand diseases and painful deaths,—he must indeed be gifted with sublime endurance or undying faith, who can still believe that out of this chaos order can come, or out of this suffering happiness and health.

In the scheme of Providence it may not be meant that man shall be healthy. Diseases of mind and of body may be the cross he has to bear; or it may be the evil against which he has to struggle, and whose shackles he is finally to unloose. The last disease will disappear, we may believe, only when man is perfect; and as in the presence of the Saviour all disease was healed, so, before perfect virtue, sorrow and suffering shall fade away. Whether the world is ever to see such a consummation, no man can say; but as ages roll on, hope does in some measure grow. In the midst of all our weaknesses, and all our many errors, we are certainly gaining knowledge, and that knowledge tells us, in no doubtful terms, that the fate of man is in his own hands.

It is undoubtedly true that we can, even now, literally choose between health or disease; not, perhaps, always individually, for the sins of our fathers may be visited upon us, or the customs of our life and the chains of our civilisation and social customs may gall us, or even our fellow-men may deny us health, or the knowledge which leads to health. But as a race, man holds his own destiny, and can choose between good and evil; and as time unrolls the scheme of the world, it is not too much to hope that the choice will be for good.

Looking only to the part of hygiene which concerns the physician, a perfect system of rules of health would, I conceive, be best arranged in an orderly series of this kind.

The rules would commence with the regulation of the mother's health while bearing her child, so that the growth of the new being should be as perfect as possible. Then, after birth, the rules (differing for each sex at certain times) would embrace three epochs;* of growth (including infancy and youth); of maturity, when for many years the body remains apparently stationary; of decay, when, without actual disease, though, doubtless, in consequence of some

growth and decay, must be studied together, just as, in fact, human physiology is imperfect without the study of all the other forms of life, animal and vegetable, which are in the world. Separated for convenience, these various studies will finally converge.

* First expressly noted by Galen.

chemical changes, molecular feebleness and death commence in some part or other, forerunning general decay and death.

In these several epochs of his life, the human being would have to be considered—

1*st*, In relation to the natural conditions which surround him, and which are essential for life, such as the air he breathes; the water he drinks; his food, the source of all bodily and mental acts; the soil which he moves on, and the sun which warms and lights him, &c.; in fact, in relation to nature at large.

2*d*, In his social and corporate relations, as a member of a community with certain customs, trades, conditions of dwellings, clothing, &c.; subjected to social and political influences, sexual relations, &c.

3*d*, In his capacity as an independent being, having within himself sources of action, in thoughts, feelings, desires, personal habits, all of which affect health, and which require self-regulation and control.

Even now, incomplete as hygiene necessarily is, such a work would, if followed, almost change the face of the world. But would it be followed?

In some cases the rules of hygiene could not be followed, however much the individual might desire to do so. For example, pure air is a necessity for health; but an individual may have little control over the air which surrounds him, and which he must draw into his lungs. He may be powerless to prevent other persons from contaminating his air, and thereby striking at the very foundation of his health and happiness. Here, as in so many other cases which demand regulation of the conduct of individuals towards each other, the State steps in for the protection of its citizens, and enacts rules which shall be binding upon all. Hence arises what is now termed "State Medicine," a matter of the greatest importance. The fact of "State Medicine" being possible, marks an epoch in which some sanitary rules receive a general consent, and indicates an advancing civilisation. Fear has been expressed lest State medicine should press too much on the individual, and should too much lessen the freedom of personal action. This, however, is not likely, as long as the State acts cautiously, and only on well-assured scientific grounds, and as long as an unshackled Press discusses with freedom every step.*

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* A watchful care over the health of the people, and a due regulation of matters which concern their health, is certainly one of the most important functions of Government. The fact that, in modern times, the subject of hygiene generally, and State Medicine in particular, has commenced to attract so much the public attention, is undoubtedly owing to the application of statistics to public health. It is impossible for any nation, or for any Government, to remain indifferent when, in figures which admit of no denial, the national amount of health and happiness, or disease and suffering, is determined. The early Statistical Reports of the Army by Tulloch, Marshall, and Balfour, directed attention to the importance of this matter. The establishment of the Registrar-General's office in 1838, and the commencement of the system of accurately recording births and deaths, will hereafter be found to be, as far as the happiness of the people is concerned, one of the most important events of our time. We owe a nation's gratitude to the Registrar-General for the persistence with which he has used his official position for the public good, and to his able coadjutors, especially to him to whose sagacity the chief fruits of the inquiry are due, to William Farr.

Another action of the Government in our day was scarcely less important. It is impossible to overrate the value of the Government Inquiry into the Health of Towns, and of the country generally, commenced nearly a quarter of a century ago by Edwin Chadwick, Southwood Smith, Neil Arnott, Sutherland, Guy, Toynbee, and others, and which has, in fact, been continued ever since, and is now vigorously carried on by the official successor of these pioneers, the medical officer to the Privy Council, Mr Simon. Consequent on this movement came the appointment of medical officers of health to the different towns and parishes. The reports published by many of these gentlemen (Letheby, Dundas Thomson, Buchanan, Lankester, Hillier, Bal-

There are, however, some cases in which the State cannot easily interfere, though the individual may be placed under unfavourable hygienic conditions by the action of others. For example, in many trades, the employed are subjected to danger from the carelessness, or avarice, or ignorance of the employers. Every year the State is, however, very properly, more and more interfering in this matter, and shielding the workman against the dangers which an ignorant or careless master brings on him.

But in other cases the State can hardly interpose with effect; and the growth of sanitary knowledge, and the pressure of public opinion, alone can work a cure, as, for example, in the case of the dwellings of our poorer classes. In many parts of the country the cottages are unfit for human beings; in many of our towns, the cupidity of builders runs up houses of the most miserable structure, for which there is unhappily no lack of applicants; or masters oblige their men to work in rooms, or to follow plans which are most detrimental to health.

But even in such cases it will, I believe, be always found that self-interest would really indicate the course which is one of the foremost rules of religion, viz., that we should do for our neighbours as for ourselves. Analyse also the effect of such selfishness and carelessness as I have referred to on the nation at large, and we shall find that the partial gain to the individual is far more than counterbalanced by the injury to the State, by the discontent, recklessness, and indifference produced in the persons who suffer, and which may have a disastrous national result. It is but too commonly forgotten that the whole nation is interested in the proper treatment of every one of its members, and in its own interest has a right to see that the relations between individuals are not such as in any way to injure the well-being of the community at large.

In many cases, again, the employer of labour finds that, by proper sanitary care of his men, he reaps at once an advantage in better and more zealous work, in fewer interruptions from ill health, &c., so that his apparent outlay is more than compensated.

This is shown in the strongest light by the army. The State employs a large number of men, whom it places under its own social and sanitary conditions. It removes from them much of the self-control with regard to

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lard, and many others), have greatly advanced the subject, and have done much to diffuse a knowledge of hygiene among the people, and at the same time to extend and render precise our knowledge of the conditions of national health. When the effect of all these researches and measures develops itself, it will be seen that even great wars and political earthquakes are really nothing in comparison with these silent social changes. Even now legislation, though fragmentary and in some respects contradictory, is beginning to exert a deep influence. In the last three years several important Acts have been passed, viz., the Sanitary Act (7th August 1866), and the Amended Sanitary Act (July 1868); the Public Health (Scotland) Act (August 1867); the Act for providing better Dwellings for Artisans and Labourers (July 1868), and the former Acts on the same subject in 1866 and 1867; the Sewage Utilisation Act (August 1867). Very considerable powers are given in these and other public Health Acts, and when the various enactments are consolidated, amended in some particulars, and with imperative instead of permissive powers, there can be no doubt of a large improvement in the health of the people at large. The Sanitary Commission, which is now about to sit, will doubtless carefully consider these matters, and remove that uncertainty in, and contradiction between, the several Acts which Mr Hutchings has lately so well pointed out ("On Difficulties which exist in administering some of the Sanitary Acts of Parliament," by James B. Hutchings, of the Medical Department of the Privy Council. London, 1869).

hygienic rules which other men possess, and is therefore bound by every principle of honest and fair contract to see that these men are in no way injured by its system. But more than this: it is as much bound by its self-interest. It has been proved over and over again that nothing is so costly in all ways as disease, and that nothing is so remunerative as the outlay which augments health, and in doing so, augments the amount and value of the work done.

It was the moral argument, as well as the financial one, which led Lord Herbert to devote his life to the task of doing justice to the soldier, of increasing the amount of his health, and moral and mental training, and, in so doing, of augmenting not only his happiness, but the value of his services to the country. And by the side of Lord Herbert in this work was one whose name will ever be dear to the country, and whose life, ever since that memorable winter at Scutari in 1855, has been given up entirely to the attempt to improve the condition of the soldier.

This book has been written to assist in carrying out one of Lord Herbert's plans, and in accordance with his wish, and with that of Lord De Grey, his friend, coadjutor, and successor.

It has, therefore, been sketched on a narrower basis than the longer treatise indicated above, which would have to deal with both sexes, all ages, and various trades and conditions.

Although, however, as dealing with Military Hygiene, and drawing its chief examples from the soldier's life, it is a work on Army sanitation, it yet includes the general principles of hygiene applicable to all men—principles which, though here stated necessarily in the briefest and barest way, are, I am persuaded, fraught with benefit to all men, if they are properly interpreted and faithfully applied.

BOOK I.

CHAPTER I.

WATER.

ARMY REGULATIONS ON THE SUBJECT OF WATER.

The Regulations for the Medical Department of Her Majesty's Army[*] frequently refer to the supply of water. In Part i. Section 2, the Inspectors and Deputy Inspectors-General are directed to "ascertain that the water-supply is good and abundant, that wells are properly covered," and "that there is no soakage from cesspools, drains, &c., into them." Also, "that the lavatories and baths are sufficient for the number of men, and that bathing parades are sufficiently frequent."

In Part iv., Section 2, the surgeon or medical officer in charge of a regiment is ordered to examine, from time to time, "the quality and amount of drinking-water," and to ascertain that there is "no soakage from latrines, cesspools, drains, or other sources of impurity." He is also ordered to inspect the lavatories and baths. In Sections 4 and 5, the same supervision over the water-supply of camps and garrisons and transport ships, is enjoined.

When an army takes the field a Sanitary Officer is appointed, and he examines into all sanitary points, including the water-supply. (Part iv. Section 6.)

In the monthly and annual Reports the water-supply has to be considered, in common with the other sanitary conditions.

The points, therefore, which the medical officer must examine are—

1. The quantity of water per head per diem.

2. Its source, collection, storage, distribution, including the conditions of reservoirs, tanks, cisterns, pipes, &c.

3. Its quality and composition.

4. In the field, the medical officer may have to indicate the sources, to measure the quantity, and to examine the quality of the water.

[*] The new Regulations were first issued in 1859. A revised issue has been lately prepared, and will probably be promulgated in 1869. I have been permitted by the Director-General to make use of the proof-sheets of the revised issue; but as it had not been paged at the time of this work going to press, I have not been able to give the pages.

SECTION I.

ON THE QUANTITY AND SUPPLY OF WATER.

Sub-Section I.—1. Quantity of Water for Healthy Men.

In estimating the quantity of water required daily for each person, it is necessary to allow a liberal supply. There should be economy and avoidance of waste; but still any error in supply had far better be on the side of excess. In England many poor families, either from the difficulty of obtaining water or of getting rid of it, or from the habits of uncleanliness thus handed down from father to son, use an extremely small amount. It would be quite incorrect to take this amount as the standard for the community at large, or even to fix the smallest quantity which will just suffice for moderate cleanliness. It is almost impossible to give a definition of cleanliness, nor perhaps is it necessary, since there is a general understanding of what is meant.

It must be clearly understood for what purposes water is supplied. It may be required for drinking, cooking, and ablution of persons, clothes, utensils, and houses; for cleansing of closets, sewers, and streets; for the drinking and washing of animals, washing of carriages and stables; for trade purposes; for extinguishing fires; for public fountains or baths, &c.

In towns supplied by water companies, the usual mode of reckoning is to divide the total daily supply in gallons by the total population, and to express the amount per head per diem.

The following are some of the gross amounts used at the present time for all the above purposes, as judged of in this way:—

	Gallons per head of population daily.
New River Company in London in 1866,*	23
East London Water-Work Company, ,,	22
Chelsea ,, ,,	33·8
West Middlesex ,, ,,	30
Grand Junction ,, ,,	34
Southwark and Vauxhall ,, ,,	21
Lambeth ,, ,,	34
Southampton, ,, ,,	35
Glasgow, ,, ,,	50
Derby,†	14
Nottingham,†	17
Norwich,†	12
Edinburgh,	35
Liverpool,	30
Sheffield,	20
Paris,	31

In 1857 the average supply to fourteen English towns, of second-rate magnitude, was 24 gallons. Mr Bateman states that in the manufacturing towns of Lancashire and Yorkshire, the present amount is from 16 to 21 gallons.

By a recent decision of the Secretary of State for War, a soldier is to

* These and the other London amounts are taken from the Report of the Committee of the House of Commons on the East London Water Bills, 1867, p. 317. The Edinburgh amount is taken from the same work.

† From Mr Beggs' pamphlet on "Constant Water Supply," issued by the Social Science Association.

receive 15 gallons daily; no extra allowance is made for the wives and children in a regiment.

The gross amount thus taken is used for different purposes, which must be now considered.

Amount for Domestic purposes, excluding Water-Closets.

This item includes drinking, cooking, washing the person, the clothes, the house utensils, and the house.

An adult requires daily about 70 to 100 ounces ($3\frac{1}{2}$ to 5 pints) of water for nutrition; but about 20 to 30 ounces of this are contained in the bread, meat, &c., of his food, and the remainder is taken in some form of liquid. There are, however, wide ranges from the average. Women drink rather less than men; children drink, of course, absolutely less, but more in proportion to their bulk than adults. The rules for transport vessels allow 8 pints in and 6 out of the tropics for cooking and drinking. During hot weather and great exertion a man will, of course, drink much more.

In some experiments made for the War Office in 1866, at the Richmond Barracks in Dublin and the Anglesey Barracks in Portsmouth, the amount of the different items of the domestic supply (excluding latrines, which take 5 gallons per head) is thus given:—

	Gallons per soldier daily.
Cook-house,	1
Ablution rooms and baths,	4
Cleaning barracks,	2·25
Wash-house and married people,	2·5
	9·75

I have measured the water used in several cases; the following was the amount used by a man in the middle class, who may be taken as a fair type of a cleanly man belonging to a fairly clean household:—

	Gallons daily per one person.
Cooking,	·75
Fluids as drink (water, tea, coffee),	·33
Ablution, including a daily sponge-bath, which took $2\frac{1}{2}$ to 3 gallons,	5
Share of utensil and house-washing,	3
Share of clothes (laundry) washing estimated,	3
	12

These results are tolerably accordant with the Dublin experiments, if we remember that with a large household there is economy of water in washing utensils and clothes, and that the number of wives and children in a regiment is not great. In poor families, who draw water from wells, I have found the amount to vary from 2 to 4 gallons per head, but then there was certainly not perfect cleanliness.

Mr Bateman* states that in a group of cottages with 82 inmates, the daily average amount was $7\frac{1}{2}$ gallons per head, and in another group 5 gallons per head. Dr Letheby found in the poor houses in the city of London the amount to be 5 gallons.† In experiments in model lodging-houses, Mr Muir states, that 7 gallons daily were used.‡ Mr Easton, in his own house in London,

* On "Constant Water Supply." By Messrs Bateman, Beggs, & Rendle. 1867.
† Report of the East London Water Bill Committee, 1867, Questions 2346 and 2347.
‡ Ibid. p. 5.

found he used about 12 gallons per head, of which about 5 were for closets, leaving 7 for other uses; but I infer that the laundry washing was not included.

In several of the instances just referred to, it may be questioned whether the amount of cleanliness was equal to what would be expected in the higher ranks. In all the instances quoted no general baths were used; but it is now becoming so common in England to have bath-rooms, that it is said they are often put even in eight-roomed houses. A general bath for an adult requires, with the smallest adult bath (*i.e.*, only 4 feet long and 1 foot 9 inches wide), 38 gallons, and many baths will contain 50 to 60 gallons. A good shower-bath will deliver 3 to 6 gallons. General baths used only once a-week will add 5 or 6 gallons to the daily consumption.

I believe we may safely estimate that for personal and domestic use, without baths, 12 gallons per head daily should be given as a usual minimum supply; and with baths and perfect cleanliness, 16 gallons should be allowed. This makes no allowance for water-closets or for unavoidable waste. If from want of supply the amount of water must be limited, 4 gallons daily per head for adults is probably the least amount which ought to be used, and in this case there could not be daily washing of the whole body, and there must be insufficient change of under-clothing.

If public baths are used the amount must be greatly increased. The largest baths the world has seen (those of Ancient Rome) demanded a supply of water so great as, according to Leslie's calculations, to raise the daily average per head to at least 300 gallons.

Amount for Water-Closets.

The common arrangements with cisterns allow any quantity of water to be poured down, and many engineers consider that the chief waste of water is owing to water-closets. In some districts, by attention to this point, the consumption has been greatly reduced; in one case from 30 to 18, and in another from 20 to 12 gallons per head. It has not yet been precisely determined what quantity should be allowed for water-closets. Small cisterns, termed water-waste preventers, are usually put up in towns with constant water supply, which give only a certain limited amount each time the closet is used. The smallest water-waste preventer holds $\frac{3}{4}$ gallon, but this is too little. The better kinds hold 1 to 2 gallons; but even 2 gallons are often insufficient to keep the pan perfectly clean; the water-waste preventer must be sometimes allowed to fill again, and be again emptied. Considering also that some persons will use the closet twice daily and sometimes oftener, and that occasionally more water must be used for thoroughly flushing the pan and soil-pipe, 6 gallons a-day per head should probably be allowed for closets. In this particular instance a false economy in the use of water is most undesirable. Water latrines require less; the amount is not precisely known; the experiments of the Royal Engineers at Dublin give an average of 5 gallons per head, but it is considered this might be reduced.

In fixing the above quantities, viz., 12 gallons per head for all domestic purposes except general baths and closets, 4 gallons additional for general baths, and 6 for water-closets, I shall be considered by some to have fixed the daily supply too high, while by others I shall be accused of the contrary fault. I have endeavoured to base it on facts, and do not think I am much in error. It is, however, necessary to make some allowance for unavoidable waste, and for extra supply to closets, and it will be a moderate estimate to allow 3 gallons daily per head for this purpose. This will make 25 gallons.

There is another reason for believing that an amount of about 25 gallons

per head should pass from every house daily into sewers, if sewers are used. It is that in most cases this quantity seems necessary to keep the sewers perfectly clear, though in some cases, no doubt, with a well-arranged and constructed sewerage, a less amount may suffice. But the complete clearage of sewers is a matter of such fundamental importance that it is necessary to take the safest course.

Amount for Animals.

From experiments conducted in some cavalry stables in 1866, by the Royal Engineers, the War Office authorities have fixed the daily supply for cavalry horses at 8 gallons, and for artillery horses at 10 gallons per horse. This is to include washing horses and carriages. The amount seems rather small. Of course the amount that horses drink varies as much as in the case of men, and depends on food, weather, and exertion ; but if a horse is allowed free access to water at all times, and this should be the case, he will drink on an average 6 to 10 gallons, and at times more. In the month of October, with cool weather, I found a horse, 16 hands high, doing 8 miles a-day carriage-work, and fed on corn and hay, drank 7½ gallons. Another carriage horse drank nearly the same amount. In a stable of cavalry horses doing very little work, and at a cool time of the year, I found the amount per horse to be 6⅓ gallons. The amount used for washing was 3 gallons daily. In hot and dirty weather the quantity for both purposes would be larger. For washing a horse requires at least 1½ gallon, and twice this amount if he is washed twice a-day. There is a saving, however, if grooms wash several horses in the same water. It is difficult to say how much is used for carriage-washing. A cow or an ox, on dry food, will drink 6 or 8 gallons ; a sheep or pig ½ to 1 gallon. In the Abyssinian expedition, the following was the calculation for the daily expenditure of water per head on shipboard :—

Elephants,	25	gallons.
Camels,	10	,,
Oxen (large draught),	6	,,
Oxen (small pack animals),	5	,,
Horses,	6	,,
Mules and ponies,	5	,,

For 20 elephants and 100 men, 50,000 gallons were put on board for a voyage of 60 days.*

Amounts required for Municipal and Trade purposes.

For municipal purposes water is taken for washing and watering streets, for fountains, for extinguishing fires, &c. The amount for these and for trade purposes will vary greatly. Professor Rankine,† who gives an average allowance of 10 gallons per head for domestic purposes, proposes 10 more for trade and town use in non-manufacturing towns, and another 10 gallons in manufacturing towns. Considering, however, the comparatively small number of horses and cows in towns as compared with the human population, and the frequent rains in this country which lessen watering of streets, these quantities might, perhaps, in most cases be halved.

If, now, the total daily amount for all purposes be stated per head of population, it will be as follows :—

* This information was derived from Major Holland, Assistant-Quartermaster-General, Abyssinian Army.

† Civil Engineering, 1862, p. 731.

	Gallons.
Domestic supply (without baths or closets),	12
Add for general baths,	4
Water-closets,	6
Unavoidable waste,	3
Total house supply,	25
Town and trade purposes, animals in non-manufacturing towns,	5*
Add for exceptional manufacturing towns,	5
	35

In India, and hot countries generally, the amounts now laid down would have to be altered. Much more must be allowed for bathing and for washing generally, while a fresh demand would arise for water to cool mats, punkahs, or air passages by evaporation. In Calcutta it is intended to supply to Europeans 30 gallons per head, and to natives 15 gallons daily.†

In Madras, it appears to be assumed that the ultimate amount used will be 20 gallons per head, including all residents.‡

2. Amount Required for Sick Men.

In hospitals a much larger quantity must be provided, as there is so much more washing and bathing. From 40 to 50 gallons per head are often used. I know of no good experiments as to the items of the consumption, but I think the following is near the truth :—

	Gallons daily.
For drinking and cooking, washing kitchen and utensils,	2 to 4
For personal washing and general baths,	18 to 20
For laundry washing,	5 to 6
Washing hospital, utensils, &c.	3 to 6
Water-closets,	10
	38 to 46

It would be very desirable to have more precise data ; possibly the amount for closets is put too high, but not greatly so when all cases are taken into account.

Sub-Section II.—Collection, Storage, and Distribution of Water.

The daily necessary quantity of water per head being determined, the next points are to collect, store, and distribute it.

1. Collection.

In many cases collections of water occur naturally in the depressions of the surface, or the commingling of small streams forms rivers. The collection by men consists almost entirely in imitating these natural processes, and in directing to, and finally arresting at some point, the rain, or the streamlets formed by the rain. The arrangements necessarily differ in each case. Rain-water is collected from roofs, or occasionally from pavements, and flags, or cemented ground ; in hilly countries, with deep ravines, a reservoir is some-

* This allowance will vary in every case, and must be very uncertain.
† Gordon's Army Hygiene, p. 426
‡ Report by Captain Tulloch on the Drainage of Madras, 1865, p. 93.

times formed by carrying a wall across a valley, which is well placed for receiving the tributary waters of the adjacent hills, or on a flatter surface trenches may be arranged, leading finally to an excavated tank.

The collection of the surface water which has not penetrated is usually aimed at, but it has been proposed by Mr Bailey-Denton* to collect the subsoil water by drainage pipes, and thus to accomplish two objects—to dry the land, and to use the water taken out of it. Below the surface the water is collected by wells, shallow, deep, and Artesian, or by boring.

With respect to wells, if they are situated near a river, and do not produce sufficient water, it has been recommended to lay perforated earthenware pipes parallel to the river, and below its fine-weather level, in trenches not less than 6 feet deep, and filled up above the pipes with fine gravel. The pipes end in the well, and water passing from the river and filtered through the gravel passes into them. The American tube-well (Norton's patent) appears to be a very useful invention. It is merely a small iron pipe driven into the ground in lengths; the water passes through small holes in the lowest part of the pipe, and is drawn up by a common or double action pump according to the depth.

All these matters fall within the province of the engineer, and the medical part of the question is chiefly restricted to the consideration of the purity of the water. The cleanliness and nature of the surface (lead, zinc, copper, &c.) on which rain falls; the kind of ground, and of cultivation, the amount of manuring, the nature of the subsoil if drainage water is used, and points of the like kind, have to be considered and supplemented by a chemical examination. It may, however, be necessary for a medical officer to determine sometimes the amount of water derived from the several sources.

Rain.—The *amount* of water given by rain can be easily calculated, if two points are known—viz., the amount of rainfall, and the area of the receiving surface. The rainfall can only be determined by a rain-gauge (the mode of constructing which is given in the chapter on PRACTICAL METEOROLOGY); the area of the receiving surface must be measured.

Supposing that it be known that the rainfall amounts to 24 inches per annum, and the area of the receiving surface (say the roof of a house) is 500 square feet;

Multiply the area by 144 (number of square inches in 1 square foot), to bring it into square inches, and multiply this by the rainfall. The product gives the number of cubic inches of rain which fall on the house-top in a year, or in any time the rainfall of which is known. This number, if divided by 277·274, or multiplied by ·003607, will give the number of gallons which the roof of the house will receive in a year (viz., in this case 6232 gallons); or, if it is wished to express it in cubic feet, the number of cubic inches must be divided by 1728 (number of cubic inches in a cubic foot), or multiplied by ·00058.

To calculate the receiving surface of the roof of a house, it is not necessary to take into account the slope of the roof. All that is required, is to ascertain the area of the flat space actually covered by the roof. The joint areas of the ground-floor rooms will be something less than the area of the roof, which also covers the thickness of the walls and the eaves.

In most English towns the amount of roof space for each person cannot be estimated higher than 60 square feet; and in some poor districts, is much less. Taking the rainfall in all England at 30 inches, and assuming that all is saved, and that there is no loss from evaporation, the receiving surface for

* On the Supply of Water to Villages and Farms, by Mr Bailey-Denton, C.E.

each person would give 940 gallons, or not quite 3 gallons a-day. But as few town houses have any reservoirs, this quantity runs in great part to waste in urban districts. In the country it is an important source of supply, being stored in cisterns or water-butts. If, instead of the roof of a house, the receiving surface be a piece of land, the amount may be calculated in the same way.* It must be understood, however, that this is the total amount reaching the ground; all of this will not be available; some will sink into the ground, and some will evaporate; the quantity lost in this way will vary with the soil and the season from one-half to seven-eighths. To facilitate these calculations, tables have been constructed by engineers, and the following portion of a table from Beardmore† will give the amount per acre.

Discharges due to Rainfall—(if the annual rainfall be equally distributed over the year.)

Rain per Annum.	Cubic Feet per Minute.		Cubic Feet per Diem.		Gallons per Diem.	
Inches.	On 1 Square Acre.	On 1 Square Mile.	On 1 Square Acre.	On 1 Square Mile.	On 1 Square Acre.	On 1 Square Mile.
1	0·006901	4·41	9·93	6,355	61·9	39,622
2	0·013802	8·83	19·87	12,720	123·8	79,245
4	0·027604	17·66	39·75	25,440	257·6	158,491
6	0·041406	26·50	59·62	38,160	371·4	237,736
8	0·055208	35·33	79·50	50,880	495·2	316,982
10	0·069011	44·16	99·37	63,600	619·0	396,228

All other quantities in the same proportion.

One inch of rain delivers 4·673 gallons on every square yard, or 22,617 gallons (101 tons by weight) on each square acre.‡

In estimating the annual yield of water from rainfall, and the yield at any one time, we ought to know

The greatest annual rainfall,
The least,
The average,
The period of the year when it falls, and
The length of the rainless season.

It must also be remembered that the amount of rainfall differs very greatly even in places near together.

Springs, Rivers.—It will often be a matter of great importance to determine the yield of springs and small rivers, as a body of men may have to be placed for some time in a particular spot, and no engineering opinion, perhaps, can be obtained.

A spring is measured most easily, by receiving the water into a vessel of known capacity, and timing the rate of filling. The spring should be opened up if necessary, and the vessel should be of large size. The vessel may be measured either by filling it first by means of a known (pint or gallon) measure, or by gauging it. If it be round or square, its capacity can be at once known by measuring it, and using the rules laid down in the chapter

* 9 square feet = 1 square yard.
4840 square yards = 1 square acre.
640 square acres = 1 square mile.

† Manual of Hydrology, p. 61.

‡ To bring cubic inches into gallons, multiply by 40 and divide by 11091.

for measuring the cubic amount of air in rooms. The capacity of the vessel in cubic feet may be brought into gallons if desirable, by multiplying by 6·23. If a tub or cask only be procurable, and if there is no pint or gallon measure at hand, the following rule may be useful:—

Take the bung diameter in inches, by measuring the circumference at the bung, dividing by 3·1416, and making an allowance for the thickness of the staves; square the bung diameter, and multiply by 39. Take the head diameter by direct measurement, and square it, and multiply by 25. Multiply one diameter by the other, and the product by 26. Add the sums, and multiply by the length of the cask; then multiply by ·000031473, and the result is given in gallons.* An example will illustrate this:—A cask had a bung diameter of 36, a head diameter of 27, and a length of 45 inches—

$$36^2 \times 39 = 50544$$
$$27^2 \times 25 = 18225$$
$$36 \times 27 \times 26 = 25272$$
$$94041$$
$$(94041 \times 45) = 4231845 \times {\cdot}000031473.$$
$$= 133{\cdot}188 \text{ imperial gallons.}$$

Where it is required to ascertain the yield of any small water-course with some nicety, it is the practice of engineers to dam up the whole stream, and convey the water by some artificial channel of known dimensions.

1. A wooden trough of a certain length, in which the depth of water and the time which a float takes to pass from one end to the other is measured.

2. A sluice of known size, in which the difference of level of the water above and below the sluice is measured.†

3. A weir formed by a plank set on edge, over which the water flows in a thin sheet, and the difference of level is measured between the top of the plank and the surface of the still water above. Then by means of a table the amount of water delivered per minute is read off. The weir must be formed of very thin board, and be perfectly level; a plumb-line has generally to be used.‡

The same object may, however, be attained with sufficient accuracy for the purposes of the medical officer by selecting a portion of the stream where the

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* Nesbit's Practical Mensuration, 1859, p. 309.

† *Discharge of water through a sluice.*—Multiply breadth of opening by the height; this gives the area of the sluice.

Discharge = area, multiplied by five times the square root of head of water in feet.—The head of water is the difference of level of the water above and below the dam, if the sluice be entirely under the lower level; or the height of the upper level above the centre of the opening, if the sluice be above the lower level.

‡ *Discharge of water over a weir 1 foot in length.*—If the weir is more or less than a foot, multiply the quantity in the table opposite the given depth by the length of the weir in feet, or decimals of a foot.

Depth falling over, inches.	Discharge per minute.	Depth falling over, inches.	Discharge per minute.
½	1·70 cubic feet.	2½	19·70 cubic feet.
1	4·82 ,, ,,	3	26·62 ,, ,,
1½	8·84 ,, ,,	3½	33·22 ,, ,,
2	13·63 ,, ,,	4	40·71 ,, ,,
4½	49·84 ,, ,,	7½	105·22 ,, ,,
5	56·86 ,, ,,	8	116·72 ,, ,,
5½	66·45 ,, ,,	8½	127·37 ,, ,,
6	75·19 ,, ,,	9	138·88 ,, ,,
6½	84·56 ,, ,,	9½	150·22 ,, ,,
7	93·93 ,, ,,	10	161·78 ,, ,,

Thus, if the weir measure 1 foot, and the depth of water falling over be 2 inches, the delivery is read at once, viz., 13·63 cubic feet, or 84·9 gallons per minute. If it be 4½ feet, the number 13·63 must be multiplied by 4·5, &c.

channel is pretty uniform for a length of, say not less than 12 or 15 yards, and in the course of which there are no eddies. Take the breadth and the average depth in three or four places, to obtain the sectional area. Then, dropping in a chip of wood, or other light object, notice how long it takes to float a certain distance over the portion of channel chosen. From this can be got the surface velocity per second, which is greater, of course, than the bottom or the mean velocity. Take four-fifths of the surface velocity (being nearly the proportion of mean to surface velocity), and multiply by the sectional area. The result will be the yield of the stream per second.

It may sometimes be worth while, if labour be at hand, to remove some of the irregularities of the channel, or even to dig a new one across the neck of a bend in the course of the stream.

The yield of a spring or small river should be determined several times, and at different periods of the day.

Wells.—The yield of wells can only be known by pumping out the water as far as can be done, and noticing the length of time required for refilling. In cases of copious flow of water, a steam-engine is necessary to make any impression; but, in other cases, pumping by hand or horse labour may be sufficient perceptibly to depress the water, and then, if the quantity taken out be measured, and the time taken for refilling the well be noted, an approximate estimate can be formed of the yield.

Permanence of Supply.—It is obvious that the permanence of the supply of a spring or small stream may often be of the greatest moment in the case of an encampment, or in the establishment of a permanent station.

In the first place, evidence should, when available, be obtained. If no evidence can be got, and if the amount and period of rain be not known, it is almost impossible to arrive at any safe conclusion. The country which forms the gathering ground for the springs or rivers should be considered. If there be an extensive background of hills, the springs towards the foot of the hills will probably be permanent. In a flat country the permanency is doubtful, unless there be some evidence from the temperature of the spring that the water comes from some depth. In limestone regions springs are often fed from subterranean reservoirs, caused by the gradual solution of the rocks by the water charged with carbonic acid; and such springs are very permanent. In the chalk districts there are few springs or streams, on account of the porosity of the soil, unless at the point the level be considerably below that of the country generally. The same may be said of the sandstone formations, both old and new; but deep wells in the sandstone often yield largely, as the permeable rocks form a vast reservoir. In the granitic and trap districts, small streams are liable to great variations, unless fed from lakes; springs are more permanent when they exist, being perhaps fed from large collections or lochs.

2. Storage.

The amount of storage required will depend on circumstances, viz., the amount used, and the ease of replenishing. It is, of course, easy to calculate the space required when these conditions are known, in this way:—The number of gallons required daily for the whole population must be divided by 6·23 to bring into cubic feet, and multiplied by the number of days which the storage must last; the product is the necessary size of the reservoir in cubic feet.

Many waters, particularly rain water, must be filtered through sand before they pass into small cisterns, and the filter should be cleaned every three or

four months. The following is a single filter recommended by the Barrack Commission* :—

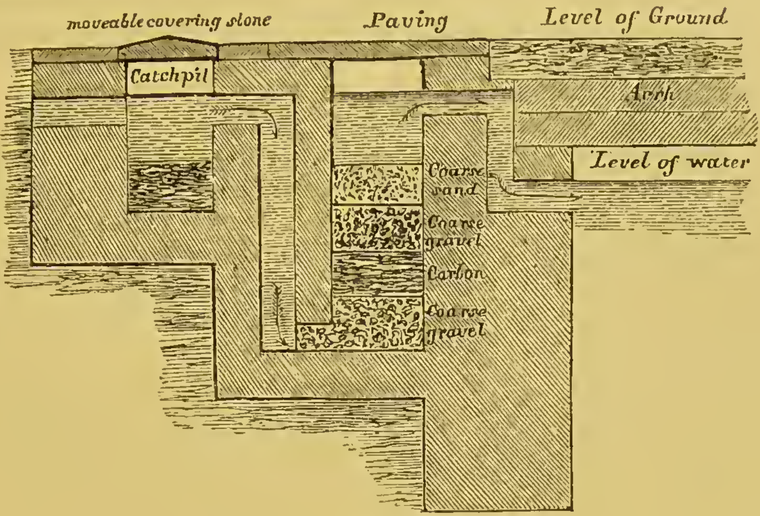

Fig. 1.

A double filter can be made by having a second chamber.

Whatever be the size of the reservoir, it should be kept carefully clean, and no possible source of contamination should be permitted. In the large reservoirs for town supply, the water is sometimes rendered impure by floods washing surface refuse into them, or by substances being thrown in. In fact, in some cases, water pure at its source becomes impure in the reservoirs.

Some large cities are still supplied principally by rain water, as Constantinople—where, under the houses, are enormous cisterns—Venice, and other places. Gibraltar is in part supplied in this way, and there was storage in the military tanks, in 1861, for 1,971,844 gallons. No house is now allowed to be built in Gibraltar without a tank. In Malta also the rain is thus stored up.

As far as possible, all reservoirs, tanks, &c., should be covered in and ventilated ; in form, they should be deep rather than extended, so as to lessen evaporation, and secure coolness. Though they should be periodically and carefully cleaned, it would appear that it is not always wise to disturb water plants which may be growing in them ; some plants, as the Protococcus, the Chara, and others, give out a very large amount of oxygen, and thus oxidise and render innocuous the organic matter which may be dissolved in the water or volatilised from the surface.† Dr Chevers mentions that the water of some tanks which were ordered to be cleared of water plants by Sir Charles Napier, deteriorated in quality. Other plants, however, as some species of duckweed (Lemna at home, Pistia in the tropics), are said to contain an acrid matter which they give off to the water. It would be well to remove some of the plant, place it in pure water in a glass vessel, and try by experiment whether the amount of organic matter in the water is increased, or whether any taste is given to the water. Dead vegetable matter should never find its way into, or at any rate remain in, a reservoir.

Whenever a reservoir is so large that it cannot be covered in, a second smaller covered tank, capable of holding a few days' supply, might be pro-

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* Report on the Mediterranean Stations, 1863.
† Clemens in Archiv. für Physiol. Heilk. 1853.

vided, and this might be fitted with a filter, through which the water of the large reservoir might be led as required.

When tanks are large, they are made of earth, stones, or masonry; if mortar be used, it should, as in the case of the smaller reservoirs, be hydraulic, so that it may not be acted on by the water.

The materials of small reservoirs and cisterns are stone, cement, brick, slate, tiles, lead, zinc, and iron. Of these slate is the best, but it is rather liable to leakage, and must be set in good cement; common mortar must not be used for stone or cement, as lime is taken up and the water becomes hard. Leaden cisterns, as in the case of leaden pipes, may yield lead to water, and should be used as little as possible, or should be protected. Lead cisterns are often corroded by mud or mortar, even when no lead is dissolved in the water. Iron cisterns and pipes are often rapidly eaten away; they are now sometimes protected by being covered inside with Portland cement. Iron tanks are now very much used. They must be covered, and in India be protected from the sun. Zinc has been said to be a good material; water acts a little upon it, but generally the compounds formed (hydrated oxide, zinc ulmate*) are almost insoluble. Nevertheless, it is said that water passing through zinc pipes, or kept in zinc pails, may produce symptoms of metallic poisoning.†

Cisterns should always be well covered, and protected as much as possible from both heat and light. Care should always be taken that there is no chance of leakage of pipes into them. A common source of contamination is an overflow pipe passing direct into a sewer, so that the sewer gases pass up, and being confined by the cover of the cistern, are absorbed by the water; to prevent this, the overflow pipe is curved so as to retain a little water and form a trap, but the water often evaporates, or the gases force their way through it; no overflow pipe should therefore open into a sewer, but should end above ground over a trapped grating. Cisterns should be periodically and carefully inspected; and in every new building, if they are placed at the top of the house, convenient means of access should be provided. Tanks to hold rain-water require constant inspection.

Wells which are really reservoirs are very liable to contamination from surface washings during rains. A good coping will often prevent this; but if there is much subsoil soaking, lining with iron to a certain depth, or covering with brickwork set in cement for a sufficient depth, to arrest the flow, may be desirable.

3. Distribution.

When houses are removed from sources of water the supply must be by aqueducts and pipes. The distribution by hand is rude and objectionable, for it is impossible to supply the proper quantity, and the risks of contamination are increased. Some of the most extraordinary of the Roman works in both the Eastern and Western Empires were undertaken for the supply of water—works whose ruins excite the astonishment and should rouse the emulation of modern nations.

The plans for the distribution of water should include arrangements for the easy and immediate removal of dirty water. This is an essential point, for in many towns where houses are not properly arranged for small families, there are no means of getting rid of water from the upper rooms, and this inconvenience actually limits the use of water, even when its supply is ample.

The supply of water to houses may be on one of two systems, intermittent

* Fonssagrives, Ann. d'Hyg. Jan. 1864, p. 857.
† My friend, Dr Orsborn, of Bitterne, has seen several cases of this kind.

or constant. The difference between the two plans is, that in the first case there is storage in the houses for from one to three days; while in the latter case, there is either no storage, or it is only on a very small scale for two purposes, viz., for water-closets and for the supply of kitchen boilers.* It should, however, be understood that the constant supply does not mean an unlimited supply, nor is it the fact that the water in the house pipes is always in direct communication with the water in the reservoirs. On the contrary, the water to the houses is often cut off, particularly in places where the supply is limited, and fittings are not good, and there is great waste.

The great argument against storage on the premises (except on a limited scale for closets and boilers) are the chances of contamination in cisterns, and the very imperfect means of storage. In poor houses wooden casks or barrels are often used, and are placed in the worst situations. The arguments against the storage system are certainly directed in part against removable failures. If every house had a good cistern, in a proper place, *i.e.*, secured from contamination, and capable of easy inspection and cleansing; if, in fact, the details of the system were good, it might be argued that storage on the premises would be the best plan, as giving without fail, and at all times of day and night, a sufficient supply of water, not merely for common use but for emergencies. It must, however, be confessed that, especially in poor houses, the inspection and cleansing even of a well-placed cistern will never be properly done, and that with all precautions the chances of contamination of the water during storage are very great. As regards this point, the constant system has a very great superiority, for there is no chance of contamination except in the reservoir or in the pipes. So great an advantage is this in a sanitary point of view, that almost all those who have paid most attention to sanitary affairs have advocated the constant system. It is, however, quite necessary that it should be understood what the constant system sometimes is in practice. When there is an abundance of water, as at Glasgow, the stoppages of water may be few, but when water has to be economised, the water is from time to time shut off from the house pipes, and then no water may be procurable for hours. This, however, is avoided as much as possible in the day time, so that the inconvenience is reduced to a minimum. In some cases, again, in order to economise water, a throttle or ferule is introduced into the communication or house pipe,† lessening the diameter to $\frac{1}{8}$th or even to $\frac{1}{16}$th of an inch, or smaller, so that if the head of pressure be small the water flows very slowly, and sometimes merely dribbles. In other cases, a meter is put on a pipe communicating with several houses; and the owner of the houses is charged for the water, and this leads him to enforce a very sparing use of it. In all these ways the constant system may tell against the consumer; while, on the other hand, great waste, leaking fittings, and fraudulent abstraction of water (to avoid which there are several ingenious contrivances) tell against the company, and lead to a depreciation of their property. Another injury is also sometimes inflicted on the company, for their fittings are stolen, and besides the loss, an enormous waste of water may be caused, and not be detected for some time.

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* Much valuable evidence on the constant supply may be found in the Report of the House of Commons Committee on the East London Water Bills, 1867. It is curious to see how difficult the definition of a constant supply was found to be. The difference of opinion between engineers on the desirability of a constant supply is shown to be considerable. The statements in the text are drawn from a collation of this evidence, and from a consideration of Mr Bateman's pamphlet, and many other works.

† The terms used to describe the pipes differ a little apparently; the mains and district or sub-mains are the large pipes, which are always full of water, the latter being of course the smaller; the service pipe is another term for a district main. The communication pipe is that which runs from the service pipe to the house, and in the house it takes the name of house pipe.

In spite of all these difficulties, the system of constant supply, in some shape or other, has been carried out in about 150 towns in England;* and after taking much evidence, a Committee of the House of Commons† has recommended that in London "every company should afford a constant supply of water to each house, so that the water may be drawn direct from the company's pipes at all times during the twenty-four hours, with the exceptions hereinafter mentioned."

In providing a constant supply, certain precautions are necessary. The fittings must be as perfect as possible. In some cases, when the system has been changed from the intermittent to the constant system, as in Chester, the waste of water has been so great that the old plan has been recurred to. Common taps do not answer, and the best screw taps and fittings must be used.‡ To prevent theft, it has been proposed to make the removal of fittings a specific offence, punished summarily by imprisonment, and to place the sale of such property under the same restrictions as in the case of Crown property.

One important sanitary advantage of the constant system is that, in order to facilitate inspection and detection of waste, no water pipe is allowed to open into a sewer, but it is always so placed that any escape of water can be easily seen. The great evil of sewer gases being conducted back into houses through overflow pipes is thus avoided. Careful inspection and good fittings so far lessen the waste of the constant system, that in some cases it has been asserted less water is used than under the intermittent plan.§

Some engineers have proposed what may be called a compromise between the intermittent and constant systems. They would allot to a house of a certain size and population a given daily amount of water, and give an equal storage, with a cistern, and would then deliver through a tube with a very small orifice an amount of water in twenty-four hours just equal to the storage. In that way the day would commence with the storage of the night, which would be sufficient for the morning washing. The water company could not lose in this way; and it would be for the tenant to look after his fittings if at any time he found himself without water. The objection to this plan is that cisterns are reintroduced, and their lessened size does not remove the objections to them.

If the constant system is used, a good stop-cock, available to the tenant, should be placed at the point of the entrance of the pipe into the house, so that the water may be turned off if pipes burst, or to allow the pipes to be empty, as during frost.

For the supply of a very large city, it might be desirable to divide the city into sections, and to establish a reservoir for each district, holding three or four days' supply. In this way the waste of one section would not take away the water from another. In some instances, people in one part of a town supplied with the constant system, have used so much water for gardens that other parts have been altogether deprived of supply. The system of secondary reservoirs would not only lessen this chance, but would make it possible to ascertain that every part of the town was getting its supply. The number of water companies in London has in fact somewhat this effect, but the subdivision is not carried far enough.

To sum up the comparative sanitary advantages of the two systems, I believe it may be said that either would answer if perfectly carried out; but

* Mr Beggs' Pamphlet, *op. cit.* page 20.

† East London Water Bills, 1867—Report, p. xvi. The recommendation has not, I believe, been yet acted upon; and, in fact, the Committee recommended that the change should be gradual.

‡ A bad ball-cock has been known to drop 12 gallons a-day.

§ Evidence of Mr Easton in the Report of Committee on the East London Water Bills, 1867.

that the constant system is safer, especially for poor houses, as it leaves no loophole for inattention in the cleansing of cisterns. Only, it requires that the constant system should really fulfil the conditions laid down for it, viz., it should deliver sufficient water and at all times, and not merely delude us with a phrase.

In both plans, the water is conducted from the reservoirs in pipes. The pipes are composed of iron, masonry, or earthenware for the larger pipes or mains, the iron being sometimes tinned or galvanised or lined with concrete; for the smaller pipes, iron, lead, tin, zinc, tinned copper, earthenware, gutta percha, &c., are used.

Bituminised paper pipes were sometime since brought into the market, but they have not succeeded; after a time they become soft. Pipes of artificial stone are now, it is said, able to be made. Iron is the best material for the larger pipes, and iron or non-metallic substances for the smaller pipes. (For the action on lead, see below.)

Water should be distributed not only to every house, but to every floor in a house. If this is not done, if labour is scarce in the houses of poor people, the water is used several times; it becomes a question of labour and trouble *versus* cleanliness and health, and the latter too often give way. Means must also be devised for the speedy removal of dirty water from houses for the same reasons. In fact, houses let out in lodgings should be looked upon, not as single houses, but as a collection of dwellings, as they really are.

ACTION OF WATER ON LEAD PIPES.

There are more discrepancies of opinion on this subject than might have been anticipated.

From an analysis of most of the works, the following points appear to be the most certain :—

1. The waters which act most on lead are the purest and most highly oxygenated; also those containing organic matter, nitrites (Medlock),* nitrates, and according to several observers, chlorides. Besides the portion dissolved, a film or crust is often formed, especially at the time of contact of water and air; this crust consists usually of 2 parts of lead carbonate and 1 part of hydrated oxide. The mud of several rivers, even the Thames, will corrode lead, probably from the organic matter it contains, but it does not necessarily follow that any lead has been dissolved in the water. Bits of mortar will also corrode lead.

2. The waters which act least on lead are those containing carbonic acid,† calcium carbonate, calcium phosphate (which has lately been found by Frankland to have a great protective power), and in a less degree, calcium sulphate; and, perhaps, in a still less degree, magnesian salts, and the alkaline phosphates;‡ but it has been said that perfectly pure water, containing no gases, has no action on lead. The deposit which frequently coats the lead, consists of lead, calcium, and magnesium, carbonate, phosphate, and sulphate, if the water have contained these salts, and lead chloride.§

3. From the observations of Graham, Hofmann, and Miller, the protective

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* Medlock attributes the greatest influence to ammonium nitrite formed from organic matter; lead nitrite is rapidly formed, and carbonate is then produced; the nitrous acid being set free to act on another portion of lead. The ammonium nitrite exists in most distilled water.

† In a late paper, M. Langlois (Rec. de Mém. de Méd. Mill. 1865, p. 412) attributes a great action on lead to the carbonic acid, but states that the carbonate of lime entirely protects lead, especially, as I understand him, by rendering the carbonic acid inactive.

‡ Report of the Government Commission, 1851, p. 7.

§ Lauder Lindsay, Action of Hard Water on Lead, p. 7.

influence of carbonic acid gas appears to be very great; a difficultly soluble lead carbonate is formed. However, a very great excess of free carbonic acid may dissolve this. This has perhaps led to the statement that carbonic acid counteracts the preservative effects of the salts.*

Other substances may find their way into water, which may act on lead—as vegetable and fatty acids, arising from fruits, vegetables, &c., or sour milk or cider, &c.

4. The lead itself is more easily acted upon if other metals, as iron, zinc, or tin, are in juxta-position; galvanic action is produced. Bending lead pipes against the grain, and thus exposing the structure of the metal, also increases the risk of solution; zinc pipes, into the composition of which lead often enters, yield lead in large quantities to water, and this has been especially the case with the distilled water on board ships.

AMOUNT OF DISSOLVED LEAD WHICH WILL PRODUCE SYMPTOMS OF POISONING.

Dr Angus Smith refers to cases of lead paralysis in which as little as $\frac{1}{100}$th of a grain per gallon was in the water. Adams also ("Trans. of the American Medical Society," 1852, p. 163) speaks of $\frac{1}{100}$th of a grain causing poisoning. Graham speaks of $\frac{1}{57}$th of a grain per gallon as being innocuous. Angus Smith says that $\frac{1}{40}$th of a grain per gallon may affect some persons, while $\frac{1}{10}$th of a grain per gallon may be required for others. But it is difficult to prove it may not at some time have been more than this. Calvert found that water which had been decidedly injurious in Manchester, contained from $\frac{1}{10}$th to $\frac{3}{10}$ths of a grain per gallon.

In the celebrated case of the poisoning of Louis Philippe's family at Claremont, the amount of lead was $\frac{7}{10}$ths of a grain per gallon; this quantity affected 34 per cent. of those who drank the water.

The water of Edinburgh is said to contain only $\frac{1}{140}$th of a grain per gallon, which is not hurtful.†

On the whole, it seems probable that any quantity over $\frac{1}{20}$th of a grain per gallon should be considered dangerous, and that some persons may even be affected by less quantities.‡

PROTECTION OF LEAD PIPES.

The chief means which have been proposed are:—

(*a.*) Lining with tin. Calvert's experiments§ show that extra tinned and ordinary tinned lead piping both gave up lead to the pure water now used at Manchester.

(*b.*) Fusible metal, viz., lead, bismuth, and tin. This is certainly objectionable.

(*c.*) Bituminous coating (M'Dougall's patent). This is said to be effectual, but I am not aware of any exact experiments.

(*d.*) Various gums, resins, gutta percha, and india-rubber. These would probably be efficacious, but I am ignorant of any evidence to show how long they will adhere.

(*e.*) Coating interior of pipes with lead sulphide by boiling the pipes in sodium sulphide for fifteen minutes. The sodium sulphide may be made by boiling sulphur in liquor sodæ. (Schwartz's patent.)

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* There is some discrepancy of opinion as to the action of the chlorides.

† Chemical News, September 28, 1861.

‡ See also Taylor's Med. Jurisp., 1865, p. 242; and opinions of Penny, ibid. p. 241.

§ Chemical News, September 28, 1861.

(*f*.) Rosin and grease with white lead (!) has been proposed, also rosin and arsenic. Both are most objectionable.

(*g*.) Varnish of coal tar.*

SUBSTITUTES FOR LEAD PIPES.

Cast and wrought iron pipes can be used, and Mr Rawlinson informs me that he now orders no others. Copper tinned and block-tin are also employed, and both are excellent, but are rather expensive. Zinc, which speedily gets covered with an insoluble oxide, can be used, if the water contains calcium carbonate, as this is said to prevent the free carbonic acid from dissolving the oxide. Gutta percha and bituminised paper pipes have been proposed, but at present are not in much, if in any, use. Artificial stone has also been employed.

SECTION II.

QUALITY OF DRINKING WATER.

SUB-SECTION I.—COMPOSITION.

The composition of water is of importance for several economic purposes; for certain trades which require careful processes of washing and dyeing; for the supply of engines, &c. But these subjects are too technical to be discussed here, and I have restricted this chapter to the quality of water as used for drinking purposes. The only domestic matter of importance connected with quality, apart from drinking and cooking, is the relative amount of soap used by hard and soft water in washing. But this is so obvious a matter that it only requires to be alluded to.

Owing to many of the domestic uses of water, such as the washing of utensils, the supply for closets, &c., not requiring a very pure water, it has been proposed in some cases to supply water from two sources—one pure for drinking and cooking, the other impure. This requires, however, two sets of pipes, and involves the chance of mistake between two waters; and it is only likely to be of use under exceptional circumstances.

Drinking water is supplied from shallow, deep, and Artesian well sources: rain, rivers, wells, springs, &c.

Rain Water.—As it falls through the air, rain becomes highly aerated (average, 25 cubic centimetres per litre), the oxygen being in larger proportion than in atmospheric air (32 per cent., or a little more); carbonic acid constitutes $2\frac{1}{2}$ or 3 per cent. of the gas. It carries down from the air ammoniacal salts (carbonate, nitrite, and nitrate), and nitrous and nitric acid in small amount. The total quantity of nitrogen in ammoniacal salts, nitrous and nitric acid, is ·000985 grammes per litre. In towns with coal-fires it takes up sulphurous and sulphuric acids, and sometimes sulphuretted hydrogen. It also carries down many solid substances, as sodium chloride, in sea air; calcium carbonate, sulphate, and phosphate; ferric oxide; carbon. It almost always contains also a little organic matter, amounting in extreme cases to as much as ·35 grains per gallon. The total amount of solids (mean of 5 analyses †) is 0·032 grammes per litre, or 2·24 grains per gallon.

Occasionally microscopic plants of the lowest order (as *Protococcus pluvialis* and others) are present.

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* Lauder Lindsay, Action of Hard Water on Lead, p. 21.

† Quoted by Moleschott, Phys. der Nadrungsmittel, 2d edit. p. 203.

Rain also often becomes very impure from taking up substances (lead, zinc, &c.) from the receiving surface on which it falls, and it also often carries down portions of leaves, &c., into the pipes and reservoirs, which slowly dissolve in it.

With regard to rain as a source of supply.—The uncertainty of the rainfall from year to year, the length of the dry season in many countries, and the large size of the reservoirs which are then required, are disadvantages. On the other hand, its purity and its great aeration make it both healthy and pleasant. The greatest benefits have resulted in many cases (especially in some of the West Indian islands) from the use of rain instead of spring or well water, which is often largely impregnated with earthy salts. In all places where the spring or well water is thus bad, as in the neutral ground at Gibraltar, rain water should be substituted. So also it has been suggested that in outbreaks of cholera anywhere, the rain water is less likely to become contaminated with sewage matters than wells or springs, into which organic matters often find their way in an unaccountable manner.

Ice and Snow Water.—In freezing, water becomes much purer, losing a large portion, sometimes the whole of its saline contents. Even calcium carbonate and sulphate are thus got rid of. The air is at the same time expelled. Ice water is thus tolerably pure, but heavy and non-aerated. Snow water contains the salts of rain water with the exception of rather less ammonia. The amounts of carbonic acid and air are very small.

There has long been an opinion that snow water is unwholesome, but this is based on no reliable observations. In Northern Europe, however, the poorer classes have the habit of taking the snow lying about their dwellings, and as this is often highly impure with substances thrown out from the house, this water may be unwholesome. It has been conjectured that the spread of cholera in the Russian winter in 1832, was owing to the use of such snow water contaminated by excretions.

Dew has occasionally been a source of supply to travellers in sterile regions in South Africa and Australia, or on board ship.

Spring, Well, and River Water.—The rain falling on the ground partly evaporates, partly runs off, and partly sinks in. The relative amounts vary with configuration and density of the ground, and with the circumstances impeding or favouring evaporation, such as temperature, movement of air, &c. In the magnesian limestone districts, about 20 per cent. penetrates; in the new red sandstone (Triassic), 25 per cent.; in the chalk, 42; in the loose tertiary sand, 90 to 96.

Penetrating into the ground, the water absorbs a large proportion of carbonic acid from the air in the interstices of the soil, which is much richer (250 times) in CO_2 than the air above. It then passes more or less deeply into the earth, and dissolves everything it meets with which can be taken up in the time, at the temperature, and by the aid of carbonic acid. In some sandy soils there is a deficiency of CO_2, and then the water is also wanting in this gas, and is not fresh and sparkling.

The chemical changes and decompositions which occur in the soil by the action of carbonic acid, and which are probably influenced by diffusion, and perhaps pressure, as well as by temperature, are extremely curious,* but cannot be entered upon here. The most common and simple are the solution of calcium carbonate, and the decomposition of calcium and sodium silicate by carbonic acid, or alkaline carbonates. Salts of ammonia also, when they exist,

* These are given in detail by G. Bischoff, "Chemical and Physical Geology" (Cavendish Society's edit.), 1854, vol. i. p. 2, *et seq.*; and in "Watt's Dictionary of Chemistry;" Article, Chemistry of Geology, by Dr Paul.

appear from Dietrich's observations to have a considerable dissolving effect on the silicates.

The general result of solution and decomposition is that the water of springs and rivers often contains a great number of constituents—some in very small, others in great amount. Some waters are so highly charged as to be termed mineral waters, and to be unfit for drinking, except as medicines. The impurities of water are not so much influenced by the depth of the spring as by the strata it passes through. The water of a surface spring, or of the deepest Artesian well, may be pure or impure. The temperature of the water also varies, and is chiefly regulated by the depth. The temperature of shallow springs alters with the season; that of deeper springs is often that of the yearly mean. In very deep springs, or in some Artesian wells, the temperature of the water is high.

The substances which are contained in spring, river, and well waters are noted more fully under the head of "Examination of Water." There may be suspended matters, mineral, vegetable, or animal; dissolved gases, viz., nitrogen, oxygen, carbonic acid, and in some cases sulphuretted hydrogen, and carburetted hydrogen; and dissolved solid matters, consisting of lime, magnesia, soda, potassa, ammonia, iron, alumina, combined with chlorine, and sulphuric, carbonic, phosphoric, nitric, nitrous, and silicic acids. More infrequently, or in special cases, certain metals, as arsenic, manganese, lead, zinc, and copper may be present.

The mode of combination of these substances is yet uncertain; it may be that the acids and bases are equally distributed among each other, or some other modes of combination may be in play. The mode of combination is *usually* assumed to be as follows.* The chemist determines the amount of each separate substance, and then calculates the combination as follows. The chlorine is combined with sodium; if there is an excess, it is combined with potassium or calcium; if there is an excess of soda, it is combined with sulphuric acid, or if still in excess, with carbonic acid. Lime is combined with excess of chlorine or sulphuric acid, or if there be no sulphuric acid or an excess of lime, with carbonic acid. Magnesia is combined with carbonic acid. So that the most usual combinations are sodium chloride; sodium sulphate; sodium carbonate; calcium carbonate (held in solution by carbonic acid); calcium sulphate; calcium chloride and silicate; and magnesium carbonate; but the results of the analysis may render other combinations necessary.

Of these various substances, the most important, in a hygienic point of view, are the vegetable and animal organic matters. They are very various in kind, and as they exist in small quantity, and are constantly undergoing changes, their exact nature is very imperfectly understood. There are, in fact, no means at present of distinguishing vegetable from animal matter, except by a consideration of the source, and very imperfectly by the characters on incineration, and by the rapidity of action on potassium permanganate. With respect to vegetable matter, almost all water contains some organic matter derived from the soil. The purest water from granitic or clay-slate districts contains from 0·3 to 0·7 grains per gallon; the purest chalk water contains from 0·3 to 1 and 1·5 grains per gallon. The sandstone waters usually contain more. If the water has permeated rich vegetable soil, it will contain a very large amount of organic matter, as much as 12 to 30 grains per gallon, and the water is then often of a yellowish or brownish tint. Water from peat often contains a large amount, and the tint is here also brownish.

In water from marshes the organic matter varies from 10 or 12 grains to

* Fresenius, Quantitative Anal. 3d edit. p. 481.

50 or 100 per gallon, or possibly in some cases more. Suspended vegetable organic matter is also common. The organic matter is nitrogenous,* and has been then called "vegetable albumen." And indeed it seems probable that a nitrogenous vegetable matter is not uncommon in water. Ammoniacal salts form in some soils also, and pass into water.

In some cases the organic vegetable matter consists of humin and ulmin, and of acids derived from humus, such as the crenic acid which on exposure becomes aprocrenic acid, ulmic acid, humic acid, and geic acid. All these acids are non-nitrogenous (Mulder), but combine eagerly with ammonia.

In waters which enter into the list of mineral waters, other nitrogenous substances are found—the so-called Glairine or the Zoogene.†

Organic matter of animal origin, and containing nitrogen, sometimes passes into water, and is then usually derived from the habitations or works of men, or from decomposing animals living in or accidentally passing into water. The contents of cesspools or sewers drain into springs, or are conducted into rivers, or the water permeates through soil impregnated more or less with these things, or manured. The exact composition of the organic matter has not been determined; urea would necessarily soon pass into carbonate of ammonia, and the other organic matters of the urine are not very stable. Nitrogenous, fæcal, and biliary matters are probably less easily decomposed, and these possibly give a large amount of the animal organic matter. But in addition, decomposed flesh and other animal matters from butchers' shops and slaughter-houses, and from dust-heaps and lay-stalls; substances from tripe-houses and gut-spinners; from size, horn, and isinglass manufactories, and from similar trades, often pass into well and spring water.

Almost all these substances in decomposing produce both nitrous and nitric acids and ammonia, and such waters are often rich in nitrites and nitrates.

Occasionally a soil not obviously contaminated will give to water large quantities of an organic matter, which oxidises rapidly into ammonium nitrates and nitrites. It appears to be of animal nature, and may perhaps arise from old animal impregnation.

Most of these animal substances, if perfectly dissolved, give no taste or smell to the water unless ammonia is found in great quantity, which is seldom the case, or sulphuretted hydrogen. A water may contain as much as ten, or even twenty grains per gallon, and be considered good by those who drink it. In those who are unaccustomed to it, or in all, apparently, under certain conditions of decomposition, such as high temperature, water of this kind may produce diarrhœal, and even choleraic symptoms, and there is some evidence to show that it predisposes to true cholera, as will be presently noted. Possibly the organic matter may, under certain conditions, commence to undergo fermentative changes, and then becomes suddenly poisonous, but nothing is really known with certainty on this point; but it seems likely that the perfectly dissolved animal organic matter is not so injurious as that which is merely suspended.

In addition to these ill-defined substances, certain fatty acids have been detected in drinking water—viz., butyric, formic, propionic, caproic, and acetic.

In a case recorded by Kraut, the water came from a marsh, and volatile fatty acids were formed on standing.‡

* In a bog water, Mr Byrne found an amount of nitrogen equal to ·17 grains per gallon.—*Proceedings of Institution of Civil Engineers*, vol. xxvi. 1867.

† Zoogene is a sort of gelatinous substance which has been noticed in the mineral waters of Baden, Ischia, and Plombières. Glairine or baregine is a somewhat similar substance found in the sulphurous waters of the Pyrenees. The "sulfuraire," a confervoid growth, is also found in this water, and has been confounded with the glairine.

‡ Ann. d. Chem. und Pharm. band cxix. p. 257, and band ciii. p. 29.

Schweizer* detected butyric acid in the water of a well, which was in part fed by the water of a trench many hundred feet distant, which was full of animal and vegetable debris. This water could not be used by men or animals, and contained no less than 1·5 grammes per litre or 105 grains per gallon of calcium butyrate.

It seems probable that this kind of contamination is more common than is supposed; and as the fatty acids are sometimes very irritating, even in small amount, their rapid formation may also occasionally lead to those symptoms of bilious vomiting and diarrhœa which water containing organic matter seems sometimes suddenly to produce, although it may have been used for some time before with impunity. But nothing certain is known on this point.

Animal organic matter is also derived from graveyards; the exact nature of the substance is here also unknown. It may be partly nitrogenous (since nitrous and nitric acid and ammonia are readily formed) and partly fatty. The injurious effect of water thus impregnated in causing diarrhœa and dysentery seems pretty well established. The detection of, and purification from, organic matter are afterwards given. The amount of organic matter in different kinds of water varies greatly, from an almost imperceptible quantity to 40 or even 60 grains per gallon. But this last amount is very rare.

Sub-Section II.—Influence of Geological Formations and other Circumstances on the Composition of Water.

The geological formation of a district necessarily influences the composition of the water running through it, though it is impossible to tell with absolute certainty what the constituents of the water will always be. Formations vary greatly, and the broad features laid down by geologists do not always suffice for our purpose. In the middle of a sandy district, yielding usually a soft water, a hard selenitic water may be found; and instead of the pure calcium carbonate water, a chalk well may yield a water hard from calcium sulphate and iron. Still it may be useful to give a short summary of the best known facts.

1. *The Granitic, Metamorphic, Trap Rock, and Clay-Slate Waters.*—Generally the granitic water is very pure, often not containing more than two to six grains per gallon of solids, viz., sodium carbonate and chloride, and a little lime and magnesia. The organic matter is in very small amount. The clay-slate water is generally very pure, often not containing more than from three to four grains per gallon.

2. *The Water from Millstone Grit and hard Oolite.*—Like the granitic water this is very pure, often not containing more than four to eight grains per gallon of mineral matters, which consist of a little calcium and magnesium sulphate and carbonate; a trace of iron.

3. *Soft Sand-Rock Waters.*—These are of variable composition, but as a rule are impure, containing much sodium chloride, sodium carbonate, sodium sulphate, iron, and a little lime and magnesia, amounting altogether to from thirty to eighty grains per gallon. The organic matter may be in large amount,—four to eight grains per gallon, or even more. Sometimes these waters are pure and soft, or wells or springs, within a short distance, may vary considerably in composition.

4. *The Loose Sand and Gravel Waters.*—In this case there is also a great variety of composition. Sometimes the water is very pure, as in the case of the Farnham waters, and in some of the waters from the greensand, where

* Oesterlen's Zt für Hygiene, band i. p. 166.

the total solids are not more than from four to eight grains per gallon, and consist of a little calcium carbonate, sulphate, and silicate; magnesium carbonate, sodium and potassium chloride; sodium and potassium sulphate; iron, and organic matter. The last is sometimes in some amount, viz., ·8 to 1·8 grains per gallon. In tolerably pure gravels, not near towns, the water is often very free from impurity. In the case of many sands, however, which are rich in salts, the water is impure, the solid contents amounting sometimes to fifty or seventy grains per gallon, or more, and consisting of sodium chloride, sodium carbonate, sodium sulphate, with calcium and magnesium salts. These waters are often alkaline, and contain a good deal of organic matter. The water from the sands in the "Landes" (Southern France) contains enough organic matter to give ague.

5. *Waters from the Lias Clays* vary in composition, but are often impure; as much as 217 grains per gallon of mineral matters have been found. No less a quantity than 88 grains of calcium sulphate, and 41·8 of magnesium sulphate, existed in a water examined by Voelcker.

6. *The Chalk Waters.*—The pure, typical calcium carbonate water from the chalk is very sparkling and clear, highly charged with carbonic acid, and contains from 7 to 20 grains per gallon of calcium carbonate, a little magnesium carbonate and sodium chloride—small and immaterial quantities of iron, silica, potassa, nitric, and phosphoric acid. Sulphuric acid in combination is sometimes present in variable amount; organic matter is usually in small amount. This is a good, wholesome, and pleasant water. It is hard, but softens greatly by boiling.*

7. *The Limestone and Magnesian Limestone Waters.*—These are also clear, sparkling waters of agreeable taste. They differ from the chalk in containing usually more calcium sulphate (4 to 12 grains, or even more) and less carbonate, and, in the case of the dolomitic districts, much magnesium sulphate and carbonate Organic matter is usually in small amount. They are not so wholesome as the chalk waters.* They are hard, and soften less on boiling.

8. *The Selenitic Waters.*—Water charged with calcium sulphate (6 to 20 grains, or even more) may occur in a variety of cases, but it may sometimes come from selenitic rocks. It is an unwholesome water, and in many persons produces dyspepsia and constipation, alternating with diarrhœa. It is hard, softens little on boiling, and is not good for cooking or washing.

9. *Clay Waters.*—Very few springs exist in the stiff clay; the water is chiefly surface, and falls soon into rivers; it varies greatly in composition, and it often contains much suspended matter, but few dissolved constituents, chiefly calcium and sodium salts.

10. *Alluvial Waters.*—(Alluvium is usually a mixture of sand and clay.) Generally impure, with calcium carbonate and sulphate, magnesium sulphate, sodium chloride and carbonate, iron, silica, and often much organic matter. Occasionally the organic matter oxidises rapidly into nitrites, and if the amount of sodium chloride is large, it might be supposed that the water had been contaminated with sewage. The amount of solids per gallon varies from 20 to 120 grains, or even more.

11. *Surface and Subsoil Water.*—Very variable in composition, but often very impure, and always to be regarded with suspicion. Heaths and moors, on primitive rocks, or hard millstone grit, may supply a pure water, which may, however, be sometimes slightly coloured with vegetable matter. Cultivated lands, with rich manured soils, give a water containing often both

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* Sometimes the water drawn from the upper part of the chalk is really derived from tertiary sand lying above the chalk. The water contains less calcium carbonate, and more sodium carbonate and chloride, and may be alkaline.

organic matter and salts in large quantity. Some soils contain potassium, sodium, and magnesium nitrates, and give up these salts in large quantity to water. This is the case in several parts of India, at Aden, and at Nassick in the Deccan (Haines). In towns, and among the habitations of men, the surface water and the shallow well water often contain large quantities of calcium and sodium nitrites, nitrates, sulphates, phosphates, and chlorides. The nitrates in this case probably arise from ammonia; ammonium nitrite being first formed, which dissolves large quantities of lime. Organic matter exists often in large amount, and slowly oxidises, forming nitric acid and ammonia. In some cases, butyric acid, which often unites with lime, is also formed.

12. *Marsh Water.*—This always contains a large amount of vegetable organic matter; from 12 to 40 and 50 grains is not uncommon, and in some cases there is more. Suspended organic matter is also common. The salts are variable. A little calcium and sodium, in combination with carbonic and sulphuric acids and chlorine, are the most usual. Of course, if the marsh is a salt one, the mineral constituents of sea water are present in varying proportions.

13. *Water from Grave-yards.*—Ammonium and calcium nitrites and nitrates, and sometimes fatty acids, and much organic matter.

14. *Water flowing from factories* may contain a great number of mineral and organic substances, including arsenic from calico-printing.

Artesian Well Water.—The composition varies greatly. In some cases the water is so highly charged with saline matter as to be undrinkable; the water of the Artesian well at Grenelle contains enough sodium and potassium carbonates to make it alkaline; in some cases the water contains iron in some amount; in other cases, especially when drawn from the lower part of the chalk, or the greensand below it, it is tolerably pure. Its temperature is usually high, in proportion to the depth of the well. The aeration of the water is often moderate. These last two points rather militate against the employment of water from very deep wells. The total solid constituents of some artesian wells is as follows:—*

	Depth in feet.	Grains per gallon.
Grenelle,	1797	10
Perpignan,	557	11
Rheims,	101	20·8
Nordmarkt, in Amsterdam,	201	99·4

River Water.

Fed from a variety of sources, river water is even more complex in its constitution than spring water; it is also more influenced by the season, and by circumstances connected with season, such as the melting of snow or ice, rains and floods, &c. The water taken on opposite sides of the same river has been found to differ slightly in composition.

Comparative Value of Spring, River, and Well Water as Sources of Supply.

This depends on so many circumstances, that little can be said. Spring water is both pure and impure in different cases; and the mere fact of its being a spring is not, as sometimes imagined, a test of goodness. Frequently, indeed, river water is purer than spring water, especially from the deposit of calcium carbonate; organic matter is, however, generally in greater quantity, as so much more vegetable matter and animal excreta find their way into it.

* Moleschott, Nahrungsmittel, 1860, p. 280.

At the same time the flow of a river tends to purify its waters; oxidation and the action of water-plants have a great effect. The water of a river may have a very different constitution from that of the springs near its banks. A good example is given by the Ouse, at York; the water of this river is derived chiefly from the millstone grit which feeds the Swale, the Ure, and the Nid, tributaries of the Ouse; the water contains only 9 grains per gallon of salts of calcium, magnesium, sodium, and a little iron. The wells in the neighbourhood pass down into the soft new red sandstone which lies below the millstone grit; the water contains as much as 64·96 grains, and even, in one case, 96 grains per gallon; in addition to the usual salts, there is much calcium chloride and calcium, sodium, and magnesium nitrates. Shallow well water is always to be viewed with suspicion; it is the natural point to which the drainage of a good deal of surrounding land tends, and heavy rains will often wash many substances into it.

Distilled Water.

Distillation is now very largely used at sea, and affords an easy way of getting good water from sea or brackish water. Almost any form of apparatus will suffice, if fuel can be procured, to obtain enough water to support life; and if even the simplest appliances are not attainable, the mere suspension of clean woollen clothing over boiling water will enable a large quantity to be collected. At sea, salt water is sometimes mixed with it from the priming of the boilers, and occasionally from decomposition of magnesium chloride (probably), a little free hydrochloric acid passes off. This can, if necessary, be neutralised by sodium carbonate.

As distilled water is nearly free from air, and is therefore unpalatable to some persons, and it is supposed indigestible, it may be aerated by allowing it to run through a cask, the bottom of which is pierced with fine holes, so as to expose the water to the air. A special apparatus for aerating the water distilled from sea water was invented by the late Dr Normandy, and is in common use. Organic matter, at first offensive to taste and smell in distilled water, can be got rid of by passing through a charcoal filter, or by keeping three or four days.

Care should be taken that no lead finds its way into the distilled water. Many cases of lead poisoning have occurred on board ships, partly from the use of *minium* in the apparatus, and partly from the use of *zinc pipes* containing lead in their composition.

Sub Section III.—Usual Sources of Contamination of Water, and Sanitary Precautions.

In examining any water, it is necessary to consider whether, in any way, some special cause of impurity has been in operation.

Rain water becomes contaminated by falling through a foul atmosphere; also, by carrying away decaying leaves or other matters from roofs of houses; it dissolves also lead from lead coatings and pipes, and takes up enough zinc from zinc roofs to be injurious. (Tardieu, *Dict. d'Hygiène*, t. 11, p. 25.)

Rivers may be rendered temporarily impure by heavy rain and floods bringing soils and vegetable debris from higher regions, or by irruptions of the sea, or by the overflow of marsh water. Shallow wells and springs are also sometimes altered in composition, by the same causes, and, if situated near the sea, may be, in dry seasons, rendered brackish by the pressure of the salt water into the land. Deep springs and wells are, of course, less affected.

The most common sources of contamination are found, however, in the habitations and trades of men. Shallow wells are very apt to be contaminated

by floods carrying in surface impurities; and by sewage soaking from cess-pits, and by matters of all kinds thrown out on the ground. To a certain extent, the soil through which these substances pass will filter and purify the water, but it must eventually lose this power, and also, at last, a complete channel may be opened, and a stream of substance may suddenly find its way into a well.

A well drains an extent of ground around it in the shape of an inverted cone, which is in proportion to its own depth and the looseness of the soil; in very loose soils a well of 60 or 80 feet will drain a large area, perhaps as much as 200 feet in diameter, or even more, but the exact amount is not, as far as I know, precisely determined. Professor Ansted states that the deepest (non-Artesian) well will not drain a cone which is more than half a mile in radius.

Certain trades pour their refuse water into rivers: gas-works; slaughter-houses; gut spinners; tripe-houses; size, horn, and isinglass manufactories; washhouses, starch-works, and calico-printers, and many others.

Gases evolved from decomposing substances, or thrown out from manufactories, are also absorbed by sheets of water, or are washed down into streams or shallow wells by rain, and in this way suspended organic substances are often carried down.

In houses, it is astonishing how many instances occur of the water of butts, cisterns, and tanks getting contaminated by leaking of pipes and other causes, such as the passage of sewer gas through overflow pipes, &c.

As there is now no doubt that typhoid fever, cholera, and dysentery may be caused by water rendered impure by the evacuations passed in those diseases, and as simple diarrhœa seems also to be largely caused by animal organic suspension or solution, it is evident how necessary it is to be quick-sighted in regard to the possible impurity of water from incidental causes of this kind. Therefore all tanks and cisterns should be inspected regularly, and any accidental source of impurity must be looked out for. Wells should be covered; a good coping put round to prevent substances being washed down; the distance from cesspits and dungheaps should be carefully noted; no sewer should be allowed to pass near a well. The same precautions should be taken with springs. In the case of rivers we must consider if contamination can result from the discharge of fæcal matters, trade refuse, &c.

SUB-SECTION IV.—CHARACTERS AND CLASSIFICATION OF DRINKING WATERS.

The general characters of good water are easily enumerated. Perfect clearness; freedom from odour or taste; coolness; good aeration; and a certain degree of softness, so that cooking operations, and especially of vegetables, can be properly performed, are obvious properties. But when we attempt a more complete description, and assign the amounts of the dissolved matters which it is desirable should not be exceeded, we find considerable difference of opinion, and also a real want of evidence, on which to base a satisfactory judgment. At the Sanitary Congress held at Brussels in 1853, it was decided that the total solids ought not to exceed 0·5 grammes per litre (= 35 grains per gallon), and the same amount had been previously laid down in the "Annuaire des Eaux de la France pour 1851" (p. 14); but this statement is really of little use, since this quantity of some salts would be hurtful, of others harmless.

Still, an hygienic classification or enumeration of potable waters, based on such facts as are generally admitted, will be useful. I have divided all kinds of waters used for drinking into four classes:—

1. Pure and wholesome water.
2. Usable ,,
3. Suspicious ,,
4. Impure ,,

And the following description will define these terms:—

HYGIENIC CLASSIFICATION OF DRINKING WATERS.

1. *Pure and Wholesome Water.*

Characters.—It should be transparent, without suspended matters, smell, or taste, and be well aerated. The total solids should not exceed 8 grains per gallon, of which only one should be dissipated by heat, unless it be a chalk water, in which case the total solids should not exceed 14 grains per gallon of calcium carbonate, and should contain only traces of calcium sulphate. The matter destructible by heat (allowance being made for the decomposition of calcium carbonate) should be under 1 grain, and should scarcely blacken; the indications of nitrites should be absent; of nitrates and ammonia extremely slight.

2. *Usable Water.*

Characters.—It should be transparent and well aerated, without suspended matters, or with only a small amount capable of easy separation by coarse filtration; without smell or taste; the total solids should not exceed 30 grains per gallon, and should consist chiefly of sodium and calcium carbonates, sodium sulphate, and chloride, and with little calcium or magnesium sulphates. The reactions of ammonia, nitrates, and nitrites should be quite inconsiderable. An exception may be made as respects the amount of total solids in the case of waters containing chiefly a mixture of sodium chloride and carbonate, in which case the conjoint salts may, it appears, run up to 50 grains, or even more per gallon, without apparent bad effects. The matters dissipated by heat should not be more than 3 grains per gallon, and there should be reason to think that the greater part of this is of vegetable origin.

3. *Suspicious Water.*

Characters.—Any water, if decidedly turbid, is suspicious, even if the turbidity be separable by coarse filtration, or if there be smell or taste. So also if the mineral matters are in large amount (over 30 grains per gallon), especially if consisting chiefly of calcium and magnesium sulphate, nitrate or nitrite, or chloride. If on drying and incinerating there is considerable blackening, or if any quantity of potassium permanganate is readily destroyed, or if the indications of nitrites and nitrates and ammonia are decided, the water is suspicious.

4. *Impure Water.*

Characters.—Any water so turbid as not to be purified by coarse filtration, or with a decided smell or taste, or containing very large quantities of mineral substances (over 50 grains per gallon), and over 4 grains per gallon of destructible (presumed) organic matter, if at the same time the indications of nitrites, nitrates, and ammonia are large, is impure. If on evaporation to dryness and careful incineration there is not only great blackening, but a decided indication of nitrous acid fumes, or a smell of burnt horn, and if a large amount of potassium permanganate is rapidly decolorised, the water is impure.

The waters belonging to the first and second class may be used; those of the third, or suspicious class, should be well filtered before distribution, and, if possible, should be again filtered in the house. A purer source should also be obtained if possible, and sources of sewage contamination ascertained and prevented.

The waters of the fourth class should be entirely disused, or only be used when a better source is not procurable, and means of purification (see page 55) should then be systematically resorted to.

SECTION III.

EXAMINATION OF DRINKING WATER.

The examination of water for hygienic purposes can be divided into the three stages of physical, chemical, and microscopical. Each mode gives important information. Water should be collected for examination in clean glass bottles, with glass stoppers and not with corks, if it can be avoided. If corks must be used, they should be new, quite clean, and the water should be soon examined. For a perfect investigation, at least a gallon of water is necessary; but a tolerably good examination can be made with a smaller quantity.

In the following account of the examination of potable water for hygienic purposes, I have endeavoured to select those processes which, while accurate and reliable, can be performed most easily and quickly, and with the least amount of apparatus. I have tried to bear in mind that medical officers will be often called upon to decide matters which are most important for health, with very scant means at their command for investigation. I have therefore endeavoured to make the instructions more detailed than is usual.

Sub-Section I.—Physical Examination.

Place some of the water, after shaking the bottle, in a tall covered glass, and allow it to stand for twenty-four hours to deposit sediment.

Colour and Transparency.—The turbidity of water is a very important point, as suspended animal matters are probably among the most dangerous ingredients, and suspended vegetable and mineral substances though less so, are sometimes hurtful. Any water which is decidedly turbid requires filtration before use. The turbidity may either be from the sources of the water, or from the channels used to distribute it, as from iron pipes or foul cisterns. The chief causes of turbidity from the source are finely divided clay, sand, ferruginous sand, chalk or marly chalk, among mineral matters; vegetable matter, such as fine loam, peat, and cells and vessels of plants; animal matter, especially sewage from men, animals, or cultivated ground. Growing plants, algæ, or fungi in large quantities, sometimes give turbidity; while animal life seldom exists in such quantity as to do so, though larvæ of insects, the water flea, and other entomostraca, can often be seen floating in the water, if a thick stratum is looked down upon, or looked through. River waters usually contain more suspended mineral and vegetable matters than spring or well water. The Rhine water contains from 1·73 to 20 parts of suspended matters per 100,000 parts, half of which consists of silica, nearly 11 per cent. of alumina, and 14½ per cent. of ferric oxide. The Danube suspended matter is about 9 parts in 100,000, and is also composed largely of silica (45 per cent.), but has in addition nearly 25 per cent. of calcium carbonate. The Mississippi and the Ganges, and in

general the large tropical streams, are much more sedimentous. In the rainy season (June to October) the Ganges has no less than 194 parts of sediment per 100,000, or 1·9 grammes per litre (= 133 grains per gallon). In the dry season the amount is hardly one-fifth of this. The Seine has suspended matters equal to ·007 to ·118 grammes per litre, or ·49 to 8·16 grains per gallon. The Thames water is thus often very turbid from finely divided clay and marly chalk, the particles of which are fine enough to pass through gravel and sand filters. When taken from the water company's stores, before going through the filters, Dr Letheby found the Thames water, in December, January, and February, to have on an average 83 grains per gallon, of which ·173 were volatile. In the early autumn it is rather more than this. Perfectly pure water is said to have a slight bluish tint when large quantities are looked through.

In examining for turbidity, place the water in a clear glass vessel, as tall as can be obtained (2 feet if possible); let the glass at the bottom of the vessel be clear and transparent, and put it on a white plate; fill it with water, and look down upon it in a good light. A similar glass filled with distilled water will give a good comparison, and a mirror placed below the glass, instead of the plate, increases the delicacy of the test. The yellowish or yellowish-white turbidity given by suspended iron sand or clay usually distinguishes those substances; vegetable matter usually gives a darkish tinge; animal (sewage) matter, if in quantity sufficient to colour the water deeply, has frequently some smell. The depth of colour is no good indication of the amount; the dark pools in farm-yards often contain little organic matter,* though what there is, is very dark-coloured. The nature of the turbidity is usually evident when the microscopic and chemical examinations have been gone through.

When water containing much carbonic acid stands for a few hours in a warm place, bubbles of the gas form on the sides of the glass; this shows that the water is well aerated.

Taste.—Any badly tasting water should be rejected, or purified before use. Suspended animal organic matters often give a peculiar taste, so also vegetable matters in stagnant waters. Some growing plants, as lemnia and pistia, give a bitter taste; but most growing plants have no taste. Perfectly dissolved animal matter is frequently quite tasteless. As regards dissolved mineral matters, taste is of little use, and differs much in different persons. On an average —†

Sodium chloride	is tasted	when it reaches	75	grains	per gallon.
Potassium ,,	,,	,,	20	,,	,,
Magnesium ,,	,,	,,	50 to 55	,,	,,
Calcium sulphate,	,,	,,	25 to 30	,,	,,
,, carbonate,	,,	,,	10 to 12	,,	,,
,, nitrate,	,,	,,	15 to 20	,,	,,
Sodium carbonate,	,,	,,	60 to 65	,,	,,
Iron, . .	,,	,,	·2	,,	,,

Iron is thus the only substance which can be tasted in very small quantities. A permanently hard water has sometimes a peculiar *fade*, or slightly saline taste, if the total salts amount to 35 to 40 grains per gallon, and the calcium sulphate amounts to 6 or 8 grains. Water nearly free from carbonic acid hardness, such as distilled water, is not so pleasant as the brisk well carbonated waters; but it is difficult to define the kind of taste or absence of it.

* Voelcker, Journal of the Royal Agricultural Society, No. 50.
† Dr de Chaumont, Army Medical Report for 1862 (vol. iv. p. 355).

Warming the water is said to increase the delicacy of taste.

Smell.—Sulphuretted hydrogen and fœtid decomposing animal substance can usually be detected when even in small quantity, although an amount of sulphuretted hydrogen, which can be readily detected by alkaline sodium nitro-prusside, may not be in sufficient quantity to give smell. When water containing animal organic substances is kept in a stoppered bottle for some time a distinct smell of butyric acid can be sometimes perceived.

Sometimes a smell can be perceived when water is evaporated or is distilled; sewage in water, though at first imperceptible, will thus give a smell both to the water in the receiver and retort. Rain water, and some kinds of river water, when badly stored, acquire a very peculiar fœtid smell, which is only in part caused by sulphuretted hydrogen.

Touch.—The only evidence derived from touch is in washing. Water containing earthy salts forms an imperfect lather, owing to the oleic acid uniting with the earthy base, and forming a precipitate. Such water is called hard; and if the hardness is great, and particularly if owing to calcium sulphate, or chloride, or to magnesium salts, it is ill adapted for cooking vegetables, as salts of lime are deposited on them, and prevent the access of water.

On the whole, the information given by the physical examination of water, though useful, is limited; and if an opinion has to be given from it alone, it should be cautiously worded, and it should be stated, not that the water is good, but that the physical examination detects nothing wrong.

Sub-Section II.—Chemical Examination.

The chemical examination may be directed either to the suspended matters, to the gases in the water, or to the mineral or organic substances dissolved in it.

1. The Suspended Matters.

The nature of the suspended matters is partly pointed out by the colour, smell, and taste, but it may be desired to know their quantity and composition. Take a measured quantity of the water (say one litre), containing an average amount of sediment, and allow it to stand in a tall narrow covered glass for 24 or 48 hours; pour off the clear water carefully as far as possible, measure the amount poured off, and put the remainder and the sediment into a weighed dish, and evaporate to perfect dryness, carrying the heat to 260° Fahr. Then weigh, and deduct from the weight the quantity of dissolved matter in the water not able to be poured off, and which quantity is known by evaporating to dryness a certain portion of the clear water. The result gives the amount of suspended matters in the litre, or whatever quantity of water had been taken.

If it be wished to know the composition of the suspended matters, incinerate, recarbonate with solution of ammonium carbonate, or solution of carbonic acid, and weigh again. The difference between the two weighings gives the amount of destructible or volatile matter in the sediment. The volatile matter of a sediment is almost sure to be organic, as the mineral sedimentous matters are not altered by heat except calcium carbonate, which will, however, have been recarbonated by the ammonium carbonate. During the incineration suspend a bit of moistened starch iodide paper over the crucible; if it becomes blue it will be from fumes of nitrous acid, which almost always arise from animal, and not from vegetable matter.

Act on the undestroyed matters with weak hydrochloric acid, and warm

gently. Note if there is effervescence (= calcium carbonate). Pour off the acid and weigh the remainder, which will be probably sand and clay. Test the acid liquid for iron, lime, and magnesia, in the modes hereafter given. The suspended matters must, of course, be examined microscopically. The sharp triangular particles of sand can be often well seen on microscopic examination in the dried sediment.

2. The Gases.

The gases in water are usually oxygen, nitrogen, and carbonic acid, and occasionally sulphuretted hydrogen and carburetted hydrogen.

The oxygen and nitrogen are not in the same proportions as in the atmosphere, but the oxygen is in relative excess, viz., 32 instead of 21 per cent. The absolute amount of oxygen and nitrogen varies, and may be as high as 7 or 8 cubic inches per gallon. The amount of oxygen depends not only on absorption from the air, but on the presence of aquatic plants which decompose carbonic acid and liberate oxygen; of fish, and other animals which breathe the oxygen and produce carbonic acid; and of dead oxidisable matters, which absorb it. Some aquatic plants give us so much oxygen that in bright sunshine little bubbles of the gas can be perceived.

The carbonic acid which is taken up by the rain from the atmosphere, especially from the air in the upper layers of the soil, exists in variable amounts, sometimes being almost absent (as in some waters from pure sands, or in springs from granite), sometimes amounting to 17 or 18 cubic inches per gallon, as in chalk waters, and in this case when the water stands in a long glass, bubbles of gas appear on the sides. When oxidisable organic matter is in the water, and is acted upon by oxygen, the carbonic acid increases at the expense of the oxygen. River water usually gives off carbonic acid, and therefore contains less than the springs or surface waters feeding the rivers. Aquatic plants grow rapidly in highly carbonated waters, as in the pure chalk waters.

The determination of the amount of these gases in the water is considered by some chemists to be very important, and the relative amount of oxygen, nitrogen, and carbonic acid, has been thought to be even a good test of the goodness of water for drinking purposes. But the various conditions dependent on plant and animal life, and movement and exposure of water, which cause alteration in the amount of oxygen, are complicated, and require to be all taken into account before a conclusion can be drawn. If the amount of oxygen ran always parallel to that of oxidisable organic matter the case would be different, but this is not so. It must be remembered also, that a water with little oxygen may be really better than one with much, because in the former case, a deleterious organic substance may have been oxidised into innocuous compounds, and in the latter may be still present. A lessening, however, in the quantity of oxygen at one part of its course which a certain water is known to contain, may be useful, as pointing out that organic matter has been in the water.

Thus Professor Miller found that Thames water contained the following amount of gases in C.C. per litre, in its flow down stream:—

	Kingston.	Hammersmith.	Somerset House.	Greenwich.	Woolwich.
Carbonic acid,	30·3	...	45·2	55·6	48·3
Oxygen, .	7·4	4·1	1·5	·25	·25
Nitrogen, .	15	15·1	16·2	15·4	14·5

The stability of the nitrogen, the increase in the carbonic acid, and the lessening of the oxygen, are well seen.

To determine the quantity of these gases, we require a mercurial trough, a

graduated tube-measure to be filled with mercury inverted in the trough, a flask, and a connecting tube with a bulb blown on it. The flask is filled with water and connected with the bulb-tube by an india-rubber tube, which is to be closed by a clamp. Some water is put into the bulb, and boiled; this is to expel air from the connecting tube; and when this is done, the end of the tube is put into the mercurial trough under the vessel filled with mercury, the clamp is removed from the india-rubber tube, and the water is cautiously boiled for an hour. The gases collect in the mercurial tube, and are measured (due regard being had to temperature and pressure, and the other corrections); the carbonic acid is absorbed by potash, the oxygen by potassium pyrogallate, and the nitrogen is read as the residue.

As regards the carbonic acid, there is an objection to this method, as the heat decomposes the calcium and magnesium bicarbonates, and therefore the amount of carbonic acid evolved is greater than existed in the water as free carbonic acid. On the other hand, it is impossible by heat alone to obtain all the oxygen and nitrogen.

As this operation is a rather delicate one, and requires some practice, and as the information it gives, in a hygienic point of view, does not appear to be so useful as that obtained by other methods, it may be omitted except in cases where the amount of aeration is considered very important. The amount of free carbonic acid can also be determined approximately by the soap solution subsequently described.

Dr Frankland has proposed a very ingenious plan for extracting the gases from water without heat. It is an application of the Sprengel pump, in which the Torricellian vacuum of a barometer is made to act as an air-pump. The gases can be extracted either at the ordinary or boiling temperature. It is probable that in laboratories where much water analyses is carried on, this plan will come into general use, but it can hardly at present be applied by army medical officers.

Hydrosulphuric acid sometimes occurs in water from the decomposition of sulphates by organic debris, even by the cork of the bottles, and then liberation of SH_2 by carbonic acid. In some mineral waters (Marienbad) sulphuretted hydrogen appears when algæ are in the water, but not without.*

If the gas is present in any quantity, it can be detected by the smell. Sulphides have, however, less smell. Both, even without smell, can be detected by salts of lead. A large quantity of water should be taken in an evaporating dish, and a little clear lead subacetate or acetate allowed to flow tranquilly over the surface. Black fibres of lead sulphide are formed. If lead acetate is mixed with solution of soda until the precipitate which at first forms is redissolved, a very delicate test-liquor is obtained. Solution of sodium nitro-prusside is also a delicate test, and gives a beautiful violet-purple colour. As it only acts on the sulphides, a little solution of soda must also be added to detect the free hydrosulphuric acid.

The amount of free hydrosulphuric acid can be readily determined by a solution of iodine in potassium iodide. Dissolve 6·35 grammes of iodine in one litre of water by the aid of a little potassium iodide. Make a solution of starch by pouring a little boiling water on good starch, then rubbing it well with cold water, and filtering, so as to get an almost clear solution. Test a little of this with a drop of iodine, to see that it is good. Take a litre of the water to be examined, put in a little solution of starch, and drop in from a burette the iodine solution, reading off the amount sufficient to give the slightest possible blue colour. As 1 C.C. of the iodine solution is equivalent

* Archiv für Wiss. Heilk, 1864, No. III. p. 261.

to 0·0008 grammes of sulphur, or 0·00085 grammes of hydrosulphuric acid, multiply the number of C.C. of the iodine solution used by ·00085, and the result will be the amount of hydrosulphuric acid in grammes per litre. Multiply this by 70, to bring into grains per gallon, and then by 2·7525, to bring the grains into cubic inches. To abridge the calculation, a short factor, obtained by multiplying the above three numbers together, may be used. This short factor is ·164.

Example.

One litre of water required 3·4 C.C. of the iodine solution.

$3{\cdot}4 \times {\cdot}00085 \times 70 \times 2{\cdot}7525 = {\cdot}557$ cubic inches per gallon.

By short Factor.

$3{\cdot}4 \times {\cdot}164 = {\cdot}557$ cubic inches per gallon.

The determination of the amount of free hydrosulphuric acid may be useful not only in the analysis of mineral waters, but also in any investigation in which disease has been traced to this gas.

Carburetted hydrogen in small quantity in water is not readily detected. Generally there are other impurities, especially if it be derived from gas impregnation. In larger quantity it sometimes bubbles up from the water of stagnant pools, particularly if there be much vegetable matter; and in the cases of some natural springs in petroleum districts, can be ignited.

3. The Dissolved Matters.

The chief dissolved matters important in a hygienic view have been already enumerated. There are great difficulties in determining the nature and amount of the vegetable and animal organic matters. Professor Frankland has lately proposed a very beautiful process for the determination of the organic nitrogen and organic carbon in water.* Unfortunately it is far too difficult, and requires too much apparatus to be commonly used for hygienic purposes. Professor Wanklyn and Mr Chapman have recommended adaptations of the ammonia test for the determination of the nitrogen in water; and as the plan is delicate and easy, it seems likely to be a good deal used. In India, Dr Macnamara of Calcutta has devised a very useful scheme, and he has done excellent service in organising a complete system of water analysis in the Bengal Presidency. By one means or other, and by properly estimating the value of the several indications, a safe opinion of the purity of drinking water can, I believe, be soon arrived at, and without much expenditure of time. It must, however, be admitted, that if it be true that an extremely minute portion of cholera discharge is sufficient to cause an attack of cholera, such a water might appear chemically pure, as chemistry cannot detect, or at any rate cannot identify, any minute quantities of organic matter of any kind. But as it is quite unknown what quantity of choleraic poison must be in the water in order to give rise to symptoms, the point can hardly be discussed at present. The chemical examination of the dissolved matters is divided into the qualitative and the quantitative. The former, simple as it is, gives very important information.

Qualitative Examination.

This should precede the quantitative, and the results should be carefully noted in the following order. Some of the tests can be applied at once to the water, but as the amount of magnesia and phosphoric acid are usually small, the water must be concentrated before the tests are applied in those cases.

1. *Reaction.*—An acid reaction, which is generally very slight, is sometimes

* Chemical Journal, March 1868, and other publications. The army surgeon will find an extract giving Dr Frankland's process in vol. viii. p. 302-3, of the Army Medical Reports, 1868.

given by waters containing much carbonic acid. It is destroyed by boiling. A marked acid reaction is very rare, except in the impurest waters. An alkaline reaction is probably so from sodium carbonate, and will be permanent. If it be from ammonia, the action is usually slighter, and is fugitive. A water with an alkaline reaction from ammonia is a very suspicious one.

2. *Organic matter.*—The neutral solution of the gold perchloride is an useful test. If the solution be acid, a little sodium carbonate should be added to neutralisation.

Take 6 or 8 ounces of the water in a flask, add 8 to 12 drops of the perchloride, and boil for some minutes. Organic matter decomposes the chloride, a dark yellow colour is given to the liquid, and the gold is eventually thrown down as a violet-coloured or almost black powder. In proportion to the depth of the colour is the amount of organic matter.

Another simple plan is to take one litre of the water, and to add a little solution of potassium permanganate. If the organic matter be large, the pink colour is very rapidly destroyed, and more permanganate must be added. Neither test shows very well the organic matter to be of animal or vegetable nature, but animal matter acts on both tests more rapidly. It should be remembered that sulphuretted hydrogen at once decomposes the permanganate.

3. *Lime.*—Test with ammonium oxalate. Six grains per gallon of a lime salt give a turpidity with ammonium oxalate; 16 grains, a considerable precipitate; 30 grains, a very large precipitate. Even from this test, an idea can be formed of the quantity of lime. Boil the water briskly for thirty minutes; if calcium carbonate be present, it will be thrown down; filter, fill up to original volume with distilled water, and again test with ammonium oxalate. As only 2 grains per gallon of calcium carbonate can remain in solution after boiling, a large precipitate will show that calcium sulphate or chloride is present.

4. *Magnesia.*—As magnesia is in small amount, great care is usually necessary in this process. Take one litre of the water, add a little ammonium oxalate, and evaporate to a very small bulk, filter, and then to the perfectly clear fluid add a few drops of solutions of ammonium chloride and sodium phosphate, and a few drops of ammonia. In twenty-four hours, if magnesia be present, crystals of ammonium-magnesium phosphate are thrown down.

5. *Potash and Soda.*—It is not often necessary to examine this point, but if it is wished to do so, the process is as follows:—Take a portion of the liquid from which lime has been thrown down; evaporate to dryness, ignite gently to drive off ammonia; if magnesia is present, it must be removed as follows:—Add baryta water, boil, filter; add to filtrate ammonium carbonate and some caustic ammonia; evaporate to dryness, adding some ammonium chloride during the process: evaporate, ignite; then dissolve in a little water, and divide into two portions.

(*a.*) Test one portion with platinum bichloride for potassa.

(*b.*) Test the other with potassium antimoniate for soda.

As this process is complex, and as potash is seldom present in large amount in drinking water, it will be generally sufficient to evaporate the water at once, and see if it is alkaline; if it is not, we may be sure no great amount of sodium carbonate is present.

6. *Chlorine.*—Add a few drops of dilute nitric acid, and then silver nitrate. Four grains per gallon of sodium chloride give a turbidity; 10 grains, a slight precipitate; 20 grains, a considerable precipitate. A guess can thus be made at the amount.

7. *Sulphuric Acid.*—Add a few drops of dilute hydrochloric acid, and then a few drops of barium chloride. If no precipitate occurs, let it stand for twenty-four hours.

Sulphates to the amount of 1, or even $1\frac{1}{2}$, grain per gallon give no precipitate; at first, or on standing, 3 grains give a haze, and after a time, a slight precipitate; above this amount, the precipitate is pretty well marked. If there is no precipitate, the presence of sulphates in small amount (1 to 2 grains per gallon) is not excluded.

8. *Phosphoric Acid.*—Add a little dilute nitric acid, and then an excess of ammonium molybdate, and boil. If PO_5 is present, a yellow colour is produced, and in time a finely powdered yellow precipitate of ammonium phosphoric molybdate falls. The yellow colour alone is not sufficient proof. Or if no ammonium molybdate be procurable, concentrate the water, filter, and add a little magnesium sulphate and liquor ammoniæ; the ammonium-magnesium phosphate is thrown down. A third test is, to add a very little dilute nitric acid, and an excess of sodium acetate, and then a drop of iron perchloride; a yellow white flocculent precipitate falls. As phosphoric acid is always in small amount, the water must be concentrated before either test is used.

9. *Nitric Acid.*—Evaporate a litre to a very small bulk; put it in a test tube; add an equal bulk of *pure* sulphuric acid;* allow to cool; and then pour in gently a little solution of ferric sulphate, so that it may form a layer above the mixed water and acid. A dark olive-green or brown ring will form at the junction of the two liquids if nitric acid be present.

Or after the water has been greatly concentrated, add a little sulphuric acid and a drop or two of sulphuric acid and indigo, and warm; the blue colour will disappear if nitric acid be present.

Another test has been lately proposed, which is still more delicate:

Brucine Test.—Dissolve 1 gramme of brucine in 1000 C.C. of distilled water. Take 1 C.C. of this solution; add 1 C.C. of the unconcentrated water, and then pour down the glass very carefully 1 C.C. of pure sulphuric acid, so that it may form a layer below the water. If nitrates are present, a zone of rose colour, which turns yellow on its under surface, appears at the junction of the two liquids. If the water contains $\frac{1}{1000}$th of nitric acid, the reaction is seen very decidedly. (Kersting, "Chemical News," October 1863.) The water used to dissolve the brucine must be pure, and should be distilled from potash. Commercial SO_3 generally contains N_2O_3, and this is a great difficulty for the army surgeon, in all the tests for nitric acid in which SO_3 is used. It ought to be distilled with 5 per cent. of ammonium carbonate, and only $\frac{3}{4}$ collected. The brucine should be carefully washed with pure water before solution.

10. *Nitrous Acid.*—Make potassium iodide starch paste by taking 1 part of pure potassium iodide, 20 parts of starch, and 500 parts of water. Take a little of this, mix it with the water, and add a little dilute pure sulphuric acid; if nitrous acid be present, a blue colour will at once appear. A comparative experiment should always be made with distilled water. Some doubts have been expressed of the accuracy of this test, but it appears to be a good one when used for drinking waters, the solids in which are in small amount. It is often necessary to concentrate the water.

11. *Ammonia*—by Nessler's test—the preparation of which is given at page 43. Ammonia gives a yellowish brown colour and eventual precipitate.

* The sulphuric acid may be tested by brucine, or by adding a particle of potassium bichromate; if nitrous acid be present, the green chromium oxide is formed. It is unfortunate that almost all the ordinary sulphuric acid of commerce contains nitric and nitrous acids, and thus a difficulty arises in using the test.

12. *Iron.*—By red and yellow potassium prussiate, or by solution of tannin, Prussian blue or black iron tannate are thrown down. Sodium sulphocyanide gives a pink tinge with ferrous salts.

13. *Sulphuretted Hydrogen*, by a salt of lead, or if it exist as sulphide, by sodium nitro-prusside, as already mentioned.

14. *Lead.*—Pass hydrosulphuric acid at once, or after evaporation, through the water. Collect the precipitate; heat it on charcoal in blowpipe flame, to get the metallic lead; dissolve the lead globule in very weak nitric acid, and add a drop of solution of potassium iodide.

If the lead is in very small quantity, acidify at least half a gallon of the water with acetic acid; add a little ammonium acetate (to prevent the lead precipitating as sulphate), evaporate to a small bulk, filter, and pass SH_2 through. Collect the lead sulphide, and proceed as above. Copper may also give a black with SH_2. Iron gives a brown colour.

15. *Arsenic*, if present, can be detected by evaporating a litre of the water previously rendered alkaline with a little sodium carbonate, acidulating the concentrated water with pure hydrochloric acid, and determining by Marsh's test or Reinsch's.

Even by these simple qualitative tests a very fair opinion may be formed of the quality of a water, or at any rate, some guidance is given. Thus, if water does not deposit calcium carbonate on boiling, and after boiling continues to give a large precipitate with ammonium oxalate, the presence of calcium sulphate, nitrate or chloride in large quantities, and not carbonate, may be inferred.

If to the qualitative tests, the quantity of solids per gallon, and the hardness of the water before and after boiling, can be determined, a very safe opinion on the goodness of the water for drinking purposes can be given at the cost of little time or labour.

If, when a small quantity of potassium permanganate be added, the discoloration occurs *very* rapidly, the organic matter is more probably animal than vegetable, or a large quantity of nitrites is present.

If a very large quantity of chlorine is present, the water is either contaminated with sea water, or with much sewage, or is drawn from strata very rich in salts, as in the case of some sands. A *large* indication of nitric or nitrous acid shows oxidation of animal matter.

The Solids in Solution.

It is unfortunate that there are no means of readily isolating and examining the various organic matters, vegetable or animal, which may be present. The chief mineral substances are determined readily by methods which are sufficiently exact for our purpose, but the amount, much more the nature, of the organic ingredients, cannot be perfectly ascertained.*

Still, by carefully weighing the evidence derived, not only from the quantitative results, but also from the physical and qualitative tests, a safe opinion can be arrived at of the degree of wholesomeness of water.†

* For determining the amount of the organic matters by weight, various plans have been employed. In the French Army Medical Department a favourite plan is precipitating by perchloride of iron, and then collecting, incinerating, and weighing, and expressing the amount in terms of iron.

† The French weights and measures are used in this work for the volumetric determinations on account of their convenience. Boxes containing them and apparatus are supplied by the Army Medical Department to military stations, and are sold by Mr Griffin, 22 Garrick Street, London.

The following are the principal quantitative processes necessary for the hygienic purposes, and they may be taken in the following order :—

1. Evaporation and incineration, for the total, fire-proof, and destructible solids.
2. Potassium permanganate test for oxidisable organic matters, nitrites, and iron.
3. Argentum nitrate test for chlorine.
4. Determination of nitric acid.
5. Nessler's test for ammonia.
6. The soap test.

1. *Evaporation and Incineration.*

Evaporation.—If very good scales are available, 200 C.C. of the water are sufficient; if the scales are inferior, 500 or 1000 C.C. of the water must be taken; allow to stand or filter through paper to separate coarse suspended matters, and then evaporate to dryness with a moderate heat, taking care that the water does not boil, else there may be loss from spurting. If the smaller quantity be taken, the whole evaporation may be conducted in one vessel (of platinum if possible); but if the larger amount must be used, the evaporation should be commenced in a large evaporating dish, and the concentrated water and deposit, if any, transferred into a small weighed crucible. The transference demands great care, so that none of the solids shall remain encrusted in the evaporating dish. All the contents of the large dish being transferred, evaporate to complete dryness in an air, water, or steam bath, keeping the heat below 212° Fahr. When the solids appear quite dry, raise the heat (in an air bath) to 260° or 270°, and keep it heated for half an hour to one hour. Weigh as soon as the capsule is cold, as the dried mass may be hygrometric.

Professor Wanklyn advises a very simple form of steam bath. A common two gallon tin can is taken, a perforated cork fitted in the mouth, and a funnel passed through the perforation; the crucible is placed in the funnel, a little roll of paper being placed between the funnel and crucible to let the steam pass. Water is boiled in the tin can.

Dr Frankland recommends that the heat shall not be carried above 212° Fahr., while some chemists advise a heat of over 300°. At 212° some water may be retained, while at 260° some organic matter may be dissipated; but as there is really loss of organic matter in some cases below 212°, and not much more at 260°, it seems safer to have the heat carried to the latter point, and to be thus sure of perfect dryness.

For the same reason (viz., not to cause loss of organic matter or ammoniacal salts) it is best not to add any sodium carbonate, unless there be any magnesium chloride in the water, when a weighed quantity of pure sodium carbonate can be added.

If the heat is only carried to 212°, it should be continued for a long time. The dried mass should be now weighed and calculated as grammes per

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Equivalents of the French weights :—

Gramme,	=	15·43 grains.
Decigramme,	=	1·543 ,,
Centigramme,	=	·1543 ,,
Milligramme,	=	·01543 ,,
Litre,	=	1·764 pints.
Cubic Centimetre,	=	16·9 minims.
28·4 C.C.,	=	1 fluid ounce av.

litre, or, what is the same thing, as milligrammes per litre,* and be also stated as grains per gallon, as that is the form in popular use.

The determination of the total solids is a most important point, and should be very carefully done. It gives a control over the other quantitative determinations, and if erroneous may make the other conclusions wrong.

Incineration.—Take the dried solids and incinerate with as low a heat as possible; watch the process, and note if there be much blackening, or if any fumes can be seen, or any smell be perceived as of burnt horn. A piece of filtering paper dipped in solution of potassium iodide and starch, and then dried, or a piece of ozone paper, should be held over the crucible to detect any nitrous acid which may be given out. After the black matter has been burnt off, allow the crucible to cool, and add a little solution of carbonic acid in water, or if this is not at hand, a few drops of solution of ammonium carbonate. This is for the purpose of recarbonating any lime which may have been made caustic. Allow to stand for an hour, heat quickly to drive off water and excess of ammonia, and weigh. The weight is that of fire-proof salts. The difference between the weight of the simply dried and the incinerated solids, give the amount of the destructible or volatile matters; these may be vegetable organic matters, animal organic matter, nitrites, sometimes nitrates, ammoniacal salts, and sometimes chlorine. Calcium carbonate, if present, though at first made caustic, will subsequently have been recarbonated.

The amount of destructible matters is important when considered with the qualitative tests for nitrites, nitrates, and ammonia. If these are in large amount, they may make up a considerable part of the destructible solids; but if they are in small amount, and if there is no reason to suppose that magnesium chloride is present, the volatile solids must be comprised of organic, vegetable, or animal matters. Incineration cannot point out which it is, though if it be the latter, there may be some smell of burning animal matter perceptible during the incineration.

Three grains per gallon of either vegetable or animal organic matter cause some blackening; six grains per gallon, a good deal; and ten grains per gallon, a great amount.

The incinerated solids may be treated with a few drops of sulphuric acid and a little distilled water; the fluid, if carefully poured off, will leave the silica, which, after washing, may be dried and weighed. The acid solution may be used to determine the amount of iron, as subsequently directed.

2. *Potassium Permanganate Test.*

Many chemists believe the indications of this test to be untrustworthy, and they refuse to use it. But when the limits of its action are kept in view,

* The quantitative results are usually expressed in this country as grains per gallon; in France, as grammes per litre. Many chemists in England, however, now express the amount as parts in 100,000 or in 1,000,000. If the amount is expressed not in grammes but as milligrammes (*i.e.*, simply dropping the decimal) per litre, it has the advantage of being the same as parts in a million. The following table will show at a glance what is meant. Example:—
The solids amounted to

0·247 grammes per litre.
= 247 milligrammes per litre.
= 247 lbs. in 1,000,000 lbs.

Grammes per litre can be brought into grains per gallon by multiplying by 70, while milligrammes per litre must be multiplied by ·07 to be brought into grains per gallon. Example:—

$0{\cdot}247 \times 70 = 17{\cdot}29$ grains per gallon.
$247 \times {\cdot}07 = 17{\cdot}29$,, ,,

As the results are generally expressed in this country as grains per gallon, I think it best always to give them in this form as well as in that of grammes per litre.

wrong conclusions can be avoided, and it gives information which can be obtained in no other way. It shows at once the presence of substances which rapidly oxidise, though there may be also unoxidisable organic matters whose presence it does not indicate.

The substances in water which are easily oxidised by permanganate are nitrites, sulphuretted hydrogen, ferrous salts, most vegetable matters derived from soils, some organic animal matters derived from soils, and a portion of the organic matter of the solid excreta of men and animals.

The substances not acted on, or only slightly so, are urea, some kinds probably of vegetable and animal organic matter, especially fatty substances, and various matters which, though not common constituents of water, may be present, such as gelatine, gum, and sugar.

A table is given by Dr Frankland of substances scarcely acted on by permanganate; they are gum-arabic, cane sugar, starch, gelatine, creatin, alcohol, urea, and hippuric acid. But several of these would seldom be present in potable water.

I have only found urea a small number of times, and then in wells with immediate percolation from cesspools. In all these cases the smell and taste, as well as the qualitative chemical tests, were conclusive against the water, even without the permanganate.

Potassium permanganate is therefore more useful as a positive than as a negative test, and its results require to be taken into account with those of incineration, and with the qualitative examination.

Before using it, the water, freed from sediment by standing, but not filtered through paper, should be carefully tested for nitrites, ferrous salts, and sulphuretted hydrogen. If these are all absent, the only other probable oxidisable substances are vegetable or animal organic matter. The permanganate alone will not distinguish between them.

If sulphuretted hydrogen be present, it may be expelled by gently warming, but not boiling the water; if ferrous salts or nitrites are present, a correction can afterwards be made.

Preparation of the Solution.—Dissolve ·395 grammes of crystallised potassium permanganate in 1 litre of pure distilled water; each C.C. = ·000395 grammes of permanganate, or ·0001 grammes of oxygen.*

To test the accuracy of this, dissolve ·7875 grammes of crystallised oxalic acid in 1 litre of water; 100 C.C. of a recently prepared solution, warmed with a little dilute sulphuric acid, should exactly decolorise 100 C.C. of the permanganate solution.

Use of the Solution—Action in the Cold.—Drs Miller, Letheby, A. Smith, and Paul, prefer acting in the cold water. For this purpose, measure 1000 C.C. of water, add 2 C.C. of hydrochloric acid, or 1 C.C. of sulphuric acid, and add the permanganate slowly from the burette every fifteen minutes, until the slightest red tint is perceptible for half-an-hour. The operation takes from two to three hours, or sometimes longer, and is tedious. Indeed, even after twenty-four hours, some oxidisable organic matter is still sometimes unoxidised; but the process cannot be continued so long, as an error is caused by the effect of light.

Action with Heat.—After mixing sulphuric acid (2 C.C.) and water, add a few drops of the permanganate to prevent loss by destruction of nitrites,

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* This is the strength of the solution recommended by Dr Miller (Journal of the Chemical Society, vol. iii. p. 121), Dr A. Smith, and Dr Paul (Watt's Dict. Chemistry, article *Water*, vol. v. p. 1029). In the two former editions of this work I used a solution containing 1 gramme per litre. But it seems to be of such importance to have uniformity of examination, that I have thought it best to adopt the strength above given.

and then raise the temperature to 140° Fahr., then remove the lamp, and drop in the permanganate solution, stirring well. Stop the moment the least red tint is produced; when it disappears, add a little more, until the tint is permanent for half-an-hour. The process takes about three-quarters of an hour; but if the red tint is permanent for only five minutes, the result is near the truth.

If any brown colour is produced, a little more acid should be added, and the process done more quickly; or if this fail, the water must be diluted with an equal quantity of pure distilled water. If a common burette, with an india-rubber tube, be used, the precaution should be taken of allowing the solution which has been in contact with the india-rubber to flow away; then the height of the fluid in the burette should be noted, and the test proceeded with as quickly as possible, as the india-rubber acts on the permanganate.

In the case of each operation, read off the C.C. of permanganate used per litre, and deduct ·6 C.C. (the amount of permanganate which will give a red tint to a litre of pure water, and which, therefore, must be in excess). The remainder will give the number of C.C. decolorised by all the oxidisable substances * in the water, and as each C.C. represents ·0001 gramme of oxygen, the quantity of oxygen which has been required is seen at once.

Example.—One litre of water required 17·6 C.C. of solution (17·6 − ·6) = 17 × ·0001 = ·0017 milligrammes of oxygen. The results may be expressed not in terms of oxygen, but as permanganate. As each C.C. contains ·000395 of permanganate, multiply this number by the quantity of C.C. used, and the result gives the amount of permanganate, thus—

(17·6 − ·6) = 17 × ·000395 = ·0067 grammes of permanganate.

The relation by weight of the oxygen or of the permanganate to the organic matter (supposing there be no other reducing substance) is variable; for the organic matter may be of different kinds originally, or in different stages of oxidation. In the case of the metropolitan waters, Dr Letheby considers the organic matter to be in the proportion of 8 parts to 1 of oxygen. Dr Woods, R.A., from a number of very careful experiments on the oxidation of sewage, concluded that the organic matter was in the proportion of 5 parts to 1 of permanganate, which is nearly equal to 20 parts to 1 of oxygen. I have found Dr Wood's numbers fairly correct when human solid excreta are dissolved in small quantities in water, and are tested before oxidation has commenced, the calculation being made on the destructible part of the sewage; but in other cases it fails, either when the organic matter is in large amount, or when it is not perfectly dissolved, but finely suspended. In the case of vegetable matter the proportion is not identical.

If Dr Woods' number be adopted, and it may be so when the organic matter is known to be sewage, multiply the amount of oxygen by 20, and the result will be the approximate amount of organic matter in grammes per litre.

Thus oxygen required = ·0017 × 20 = ·0340 grammes of organic matter per litre; ·034 × 70 = 2·380 grains per gallon.

The amount of oxygen thus used represents, as already stated, not only

* Instead of acting in this way, Dr Miller recommends adding a measured excess of permanganate to the water, leaving it for three hours, and then adding a little solution of potassium iodide and starch; free iodine is liberated in proportion to the excess of permanganate. The amount of free iodine is readily determined by a solution of disodic hyposulphite, containing 1 gramme per litre, which must be added till the blue tint is destroyed. Each C.C. of this corresponds to the amount of iodine liberated by 1 C.C. of the permanganate, so that the amount of excess of permanganate in C.C. is equal to the amount of sodium hyposulphite in C.C. The difference, therefore, gives the amount of permanganate destroyed by the solution in the water. The amount of hyposulphite used must be read off the moment the blue tint disappears, or, on standing, it returns. Sodium hyposulphite is now so commonly used in photography that it can probably be easily procured in every military station.

organic matter, but nitrites and ferrous salts. These may be absent, but nitrites at any rate are probably present.

If so, the results must be stated as oxygen required for oxidisable organic matter and nitrites, but an approximate determination can be come to of the amount of the latter, and the amount of permanganate required for organic matter alone thus determined.

Determination of Nitrous Acid by Permanganate.

Two or three plans have been proposed for this. Dr Paul* recommends as follows :—Take 1000 C.C. of the water, add a little aluminum chloride, and then a little sodium carbonate, and evaporate slowly to about $\frac{1}{10}$th. The organic matter is thrown down; allow to stand, and decant one-half of the water; add 450 C.C. of pure distilled water, and determine the amount of permanganate required in the cold. Multiply by 2 to get the amount per litre. As much of the organic matter is thrown down, an approximate estimate is found of the nitrites. Each C.C. of the permanganate solution = ·0002875 grammes NO_2. In case aluminum chloride is not available, add a few drops of solutions of calcium chloride and sodium carbonate to the water, and then 2 or 3 grains of alum.

Dr de Chaumont proposes the following plan :—After the total permanganate required is known, take 500 C.C. of the water, and add 10 C.C. of dilute sulphuric acid; boil well for five minutes, allow to cool to 140°; then add the permanganate. As the nitrous acid is driven off, the difference in the amount of C.C. of the permanganate used in the first and second trials, if multiplied by ·0002875, gives approximatively the nitrous acid.

Determination of Iron by Permanganate.

Evaporate a litre of water to dryness; incinerate; dissolve in 10 C.C. of dilute sulphuric acid (1 in 10), aiding it by warmth; put in a piece of granulated zinc to reduce the persalts of iron, and after effervescence has gone on for some little time, and the fluid is colourless, pour off the fluid, dilute to 1000 C.C. (or to 100 if the iron is in small quantity) with distilled water, heat to 140° Fahr., and drop in the permanganate, stopping when the least red tint is perceptible; read off the amount, and correct for colour, by deducting ·6 C.C.

1 C.C. of the permanganate solution = ·0007 iron (Fe.)
" " = ·0009 ferrous oxide (FeO.)

General Statement of the Results of the Permanganate Examination.

This should be made in the following way :—

Example—

	Grammes of Oxygen.
1. Gross amount of oxygen required per litre, at a temperature of and in the presence of sulphuric acid,	·0013
2. Amount for ferrous salts, ...	·0005
3. Amount for nitrites, ...	·0002
4. Amount for sulphuretted hydrogen, . .	not present.
5. Amount for oxidisable organic matter, . . .	.0006

* Watt's Dict. of Chemistry, vol. v. p. 1032. A plan devised by Mr Tichborne is given in my Review of Hygiene in the Army Medical Department Report, vol. viii. p. 304. The difference in the amount of permanganate used before and after evaporation to dryness and re-solution, is considered to be due to nitrites. The difficulty of this process consists in the chance of the organic matter being altered by the evaporation to dryness.

If, in addition, the weight of the organic matter be given, by using Dr Wood's or any other plan, the factor should be stated.

In a very good water it will be found that not more than 2 or 3 C.C. of the solution will be used, but most usable waters will take from 6 to 10 C.C.

Anything over this amount shows a good deal of oxidisable matter of some kind.

3. *Examination for Chlorine.*

Chlorine is present in most waters, but often in small quantity. If it be in large amount, it is derived probably from one of three sources—from sands or sandstone rocks, or other formation rich in salt; or from the percolation of the sea; or from sewage contamination. In the first case, the water will probably be also alkaline; in the second, the large amount of mineral solids, and the small amount of organic matters, as well as the situation of the spring or well, will show the source; in the third case, there is almost certain to be also present nitrates, phosphates, and some oxidisable matters acting largely on the potassium permanganate.

Chlorine may be determined very rapidly by the volumetric method.

Make a solution of pure silver nitrate,* by dissolving 17 grammes (one-tenth of an equivalent) in 1 litre of water. Of this solution 1 C.C. = 0·00355 of chlorine, or 0·00585 of sodium chloride.

If the preliminary test shows a very small quantity of chlorine, a litre must be evaporated to a small bulk; if the chlorine be in large amount, take at once a litre of the water to be examined; add enough solution of yellow potassium chromate to make the solution just yellow, and drop in the silver nitrate from the burette, and stir after each addition. The red silver chromate which is first formed will disappear as long as any chlorine is present. Stop directly the least red tint is permanent. Deduct 0·1 C.C. if the water has been evaporated, or 0·6 C.C. if it has not been evaporated, from the amount of C.C. used, and multiply the remainder by the co-efficient of chlorine, or of sodium chloride if it be assumed that that salt only is present. Neither solution of silver nor the water must be acid; if the latter is acid, a little sodium carbonate must be added.

Example.—A litre of water was evaporated to about an ounce.

A few drops of potassium chromate, and 16·4 C.C. gave a red colour—$(16{\cdot}4 - {\cdot}1) \times {\cdot}00355 = 0{\cdot}0578$ grammes per litre; $0{\cdot}578 \times 70 = 4{\cdot}04$ grains per gallon.

This calculation may be shortly performed by multiplying the number of C.C. used (after correction for colour), by ·248. The result is grains per gallon.

If it be reckoned as sodium chloride, the factor should be ·409.

This process is very useful for determining the amount of salt in various articles of food and drink. In water it is extremely so.

4. *Dr Macnamara's Test for Nitric Acid.*

It is unfortunate that the tests for such small quantities of nitric acid as exist in water are difficult. Dr Miller recommends the process known as Pugh's, Dr Frankland follows a modification of the plan suggested by Crum, and Professor Wanklyn has proposed another method. Unfortunately all are too difficult for medical officers; and yet it is very desirable to have

* The common lunar caustic may be used, but as this is impure, whenever it can be done it should be dissolved, filtered, and crystallised, and 17 grammes (= 262·2 grains) taken. Or pure silver may be dissolved in nitric acid and crystallised. The best proportions are 10·797 grammes (166·6 grains) in pure acid; driving off all fumes, and dissolving in a litre of water. If kept in crystals, it must be carefully dried, and kept in a dark place.

some idea of the amount of nitric acid. In Bengal, Dr Macnamara has made use of a plan which has the great merit of simplicity; and, as it has been used in the Government inquiries, it is desirable medical officers should know it.* Instead, however, of the English weights, it might be well to substitute grammes per litre; the equivalent strength to Dr Macnamara's solution would be ·4 grammes per litre of pure potassium nitrate, which would be equivalent to ·217 grammes of nitric anhydride (N_2O_5). The standard time and the manipulation of the plan would be of course the same as stated in the footnote below.

5. *Nessler's Test for Ammonia.*

Ammonia and its salts pass into drinking water in various ways. 1*st*,

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* Scheme for the Analysis of Potable Waters, compiled for the Use of Medical Officers, by F. N. Macnamara, M.D., Professor of Chemistry, Calcutta, p. 6. The following is Dr Macnamara's account of his plan :—

"DETERMINATION OF NITRIC ACID.

"Unfortunately there is no ready method for the exact determination of nitric acid, but the following process, carefully performed, gives very useful approximative results, and in practice is easy and rapid in its application.

"Having first prepared a solution of pure nitrate of potash containing 28·08 grains of the salt, equal to 15 grains of anhydrous nitric acid, in 1 gallon of distilled water, take a small test-tube about 4 inches in length, introduce into it 30 measured grains of the solution of nitrate of potash, and 20 measured grains of strong sulphuric acid; while adding the acid, the lower part of the tube should be kept immersed in water; now thoroughly mix by stirring the acid and the solution, and instead of a stirring-rod make use of the thermometer, the temperature will at first rise and then again fall; as soon as the temperature begins to fall, raise the test-tube from the water, and continue the stirring till the temperature has fallen to 104° Fahr. (40° cent.). The tube should then be placed in the stand with a common visiting card, bent into a curve, behind and partly surrounding it, and in the angle of a right angle of which one of the sides is a line passing from a window to the tube, and the other a line passing from the tube to the observer's eye, which should be on a level with the contents of the tube. A crystal of sulphate of iron, about the size of a small pea, previously coiled in the end of a piece of thin platinum wire, immediately on the tube being placed in position, should be suspended in the acid solution about three-fourths of its depth below the surface; in a short time a brown colour will appear in the solution, it may be in a layer above or below the crystal, or in feathery clouds stretching up from the crystal towards the surface of the fluid. The time that elapses before the colour appears should be noted, and this will constitute the standard time for the acid and sulphate of iron in use. The standard time should not be less than two minutes, and if the colour appears in less than two minutes, the sulphuric acid should be diluted and tried again, and a quantity of it of the proper strength should be kept for use. Say the standard time is from 2 to $2\frac{1}{2}$ minutes; now operate precisely in the same way with the water under examination. If the colour appears in the standard time, it contains about 15 grains to the gallon of nitric acid; if it appears more quickly, the water contains more than 15 grains of nitric acid, and the quantity may be determined by diluting the water and operating. If the colour does not appear in the standard time, evaporate down some of the water to one-half its bulk, and dry again; if the colour appears in less than the standard time, the water contains more than 7·5 grains of nitric acid to the gallon; if it does not appear, the water contains less than that amount of the acid. In the case of its containing more, dilute some of the concentrated water with one-half its bulk of water, and again operate; now, if the colour appears in the standard time, the water contains about 11·25 of nitric acid to the gallon; if it appears in less than the standard time, between 11·25 and 15 grains of nitric acid; if it does not appear in the standard time, between 11·25 and 7·5 grains of nitric acid.

"In the case of the colour not appearing in the concentrated water in the standard time, take some of the original water, 3000 grains, and evaporate down to $\frac{1}{15}$th its bulk, or 200 grains (a small test-tube graduated to 50-100-150-200 grains should be prepared for use in this examination); then apply the test. If the colour appears in the standard time, the original water contains 1 grain to the gallon of nitric acid. If the colour does not appear in the standard time, the water contains less than 1 grain to the gallon. If the colour appears in less than the standard time, dilute the concentrated water with two and three-fourths its bulk of distilled water (8 of the concentrated water with 22 of distilled water), and then apply the test. Now, if the colour appears in the standard time, the water contains about 3·25 of nitric acid; if in less than the standard time, between that and 7·5 of acid; and if the development of the colour be delayed beyond the standard time, between 3·25 and 1 grain of nitric acid.

"If the concentrated water is very alkaline, it should be feebly acidulated by the cautious addition of dilute sulphuric acid, and should then be rendered faintly alkaline by the addition of a dilute solution of carbonate of soda before applying the test."

from the atmosphere in the form of carbonate, nitrate, nitrite, chloride, and sulphide. The total ammonia from these sources seldom exceeds ·00079 grammes per litre in the country; while in the rain which has passed through town atmospheres, it may amount to ·003, or even (Bineau in Lyons) to ·03 grammes per litre. 2*d*, From vegetable matter in or on the ground, and probably especially from marshy ground. 3*d*, From animal, and especially sewage, matter in or on the ground. As it arises from so many sources, care is necessary in drawing inferences from the test. If it be accompanied by nitrites and nitrates in large amount, its origin from animal matters is probable.

The very delicate test discovered by Nessler has been applied by Professor Miller and Mr Hadow, and more recently by Professor Frankland, and by Professor Wanklyn and Mr Chapman.* In the following account I have adopted the processes employed by the latter gentlemen, as convenient and easy, without, however, venturing to express an opinion as to the value of all parts.

It is necessary to prepare Nessler's solution very carefully; a standard solution of ammonium chloride and distilled water perfectly free from ammonia are also required.

Preparation of Nessler's Solution.—Take 50 grammes of potassium iodide, and dissolve in a small quantity of hot distilled water; place in a water-bath, and add a strong aqueous solution of corrosive sublimate, until the precipitate ceases to disappear; filter, and add to the filtrate 150 C.C. of strong caustic soda, or 200 grammes of solid potash dissolved in water. Dilute to 1 litre, and add 5 C.C. of a saturated aqueous solution of mercury bichloride. Allow to subside, decant the clear liquid, and keep it in a dark place.

Standard Solution of Ammonium Chloride.—Make a solution of ammonium chloride by dissolving ·0315 grammes in a litre of water; this is equivalent to ·01 gramme of ammonia (NH_3) in the litre; in other words, each C.C. will represent ·00001 of ammonia.

Instead of weighing ·0315 grammes, it is best to make a solution of ten times the strength (viz., ·315 per litre), and to dilute it when required by adding nine parts of water to one of the liquid.

Pure Distilled Water.—If distilled water is redistilled, and the first portion be rejected, the next portion is usually free from ammonia. Or the water may be distilled from potassium permanganate. Before the test is used, the water should itself be tested with Nessler's solution.

These solutions being ready, the following processes are gone through:—

I. Take a glass cylindrical vessel, and put in 100 C.C. of the water to be examined; add 1½ C.C. of Nessler's solution; if there be ammonia, a yellowish brown colour will be given; then put into another cylinder as many C.C. of the standard ammonium chloride solution as may be thought necessary (practice soon shows the amount), and fill up to 100 C.C. with the pure distilled water; drop in 1½ C.C. of Nessler's solution. If the colours in the two cylinders correspond, the amount of ammonia in the water under examination will be the same as the amount in the solution of ammonium chloride put into the second cylinder. If the colours are not the same, the second cylinder must be emptied and another quantity of ammonium chloride used, and so on till the two cylinders show precisely the same shade of colour.

Example.—To give equal colour, 16 C.C. of standard solution had to be put in No. 2 cylinder. Therefore, there were ·00016 grammes of ammonia in the 100 C.C. of water, or ·0016 per litre.

* On Water Analysis, 1868.

The only difficulty in this process is when the water to be examined is very impure. Several substances interfere with the Nessler test. Wanklyn recommends the following plan to elude this difficulty :—Take 500 C.C., add a few drops of solution of calcium chloride and a slight drop of potash, and filter; put into a retort, and distil till the distillate is free from ammonia; then make up the fluid in the retort to 500 C.C. with pure distilled water. If, as is possible, a retort cannot be obtained, the water can be simply evaporated to one-half, and afterwards made up to 500 by distilled water. Then take 200 C.C. of the original water, add a little calcium chloride and potash as before, and filter through a washed filter. We have now two waters, both equal as regards impurities, but from one of which the ammonia has been driven off by distillation or evaporation. Add to both $1\frac{1}{2}$ C.C. of Nessler's solution, and then add to the distilled portion enough standard solution of ammonium chloride to make its colour equal to the other. The quantity of the standard solution necessary for this represents the ammonia which has been expelled.

II. The test comes out much better if the water be distilled, and if the distillate be tested for ammonia. Miller and Hadow proposed liquor barytæ for this purpose. Wanklyn and Chapman prefer sodium carbonate, and carry the plan further by a subsequent use of potash and potassium permanganate. Their process is as follows :—

They place in a retort 500 C.C. of the water and 15 C.C. of saturated solution of sodium carbonate, and distil 100 C.C., or more if there be much ammonia; the distillation is continued until 50 C.C. of the distillate contain less than ·00001 of ammonia.

Then they remove the distillate, and add to the fluid in the retort 50 C.C. of a solution of potash and potassium permanganate (made by dissolving 200 grammes of solid caustic potash and 8 grammes of potassium permanganate in a litre of water), and distil 200 C.C. more.

The ammonia is determined as before in the first and second distillate, by comparison of the colour with the standard ammonium chloride solution and distilled water.

The first distillate contains the ammonia present as such in the water, and also some derived from urea, if present. This will be the case also in Professor Miller's process with liquor barytæ. The second distillate contains ammonia derived, it is presumed, from nitrogenous or albumenoid substances.

The result is stated as follows :—The ammonia driven off by the soda is called "Free NH_3;" and that liberated by the potassium permanganate is called "Albumenoid NH_3."

Wanklyn believes that the nitrogenous substances give out a constant quantity of ammonia when thus treated by potassium permanganate; but the ratio differs in different substances, and it is not possible, apparently, to state to what quality of nitrogenous organic impurity a certain amount of "albumenoid ammonia" corresponds.* On the whole, the exact meaning and utility of this ingenious process remains to be determined by future experiments.

* If the analysis be performed in this way, the following statements from Wanklyn's Treatise (p. 59, *et seq.*), may be useful as comparisons :—

	Milligrammes per litre.	
	Free NH_3.	Albumenoid NH_3.
Loch Katrine Water (very pure),	·004	·080
Edinburgh Water supply,	·004	·034
Manchester (Brazennose Street),	·006	·060
East London Water Company,	·030	·089
Thames, from river at Hampton Court,	·045	·280
Pump in Bishopgate Street (very impure)	7·500	·255
Well in a village near London (highly impure),	40·000	3·000

The distillation demands great precaution; the ammonia must be thoroughly condensed by the use of Liebig's condenser, and the greatest care is necessary in thorough washing of all the apparatus after use.

6. *The Soap Test.**

This very useful test, invented by Dr Clark of Aberdeen, enables an opinion to be formed in a very short time of the total amount of earthy salts, and with a little care an approximate estimate can be made of the amount of the individual earthy salts and of the sulphuric acid.† The processes with the soap test may be divided into two headings.

(*a.*) The determination of the aggregate earthy salts, as expressed by the term hardness. The aggregate determination can be divided into two kinds of hardness, in that which is unaffected and that which is affected by boiling, and these are termed the permanent and the removable hardness.

(*b.*) The determination of the amount of certain constituents, as the lime, magnesia, sulphuric acid, and free carbonic acid. These results are only approximative, especially in the case of the magnesia; but they are very useful, as they give us enough information for hygienic purposes, and are done in a very short time.

Apparatus required for the Soap Test.—Burette, divided into tenths of a cubic centimeter; measure of 50 C.C. or 100 C.C.; stoppered bottles of about 4 ounces capacity.

Solutions required.—1. Standard solution of calcium chloride. Dissolve 0·1 gramme of pure calcium carbonate (white marble or Iceland spar) in pure hydrochloric acid; evaporate to dryness; dissolve; evaporate again to dryness, and do this till the *solution* is perfectly neutral. Then dilute with pure water to 1000 C.C. In English weight this is 7 grains of calcium carbonate to 1 gallon. Label this, "*Standard solution of calcium chloride.*"

2. The best way is to make a solution of ten times the strength (1 gramme to 1 litre), or 7 grains to $\frac{1}{10}$th of the gallon (= 16 ounces), and to dilute when required. Label, "*Concentrated solution of calcium chloride*—1 to 10."

If a litre of the stronger solution be made, it will last for many years.

3. Instead of the lime solutions, barium nitrate may be employed. All the trouble of evaporation is avoided. The strength of the standard solution is 0·26 grammes of pure barium nitrate to 1 litre of water; of the concentrated solution, ten times this strength, or 2·6 grammes per litre. In English weights these are 18·2 grains per gallon for the standard, or 18·2 grains to 16 ounces for the concentrated solution; 1 part of which has to be diluted with 9 parts of water when used.

4. Solution of Soap. Dissolve a piece of soft potash soap of the Pharmacopœia in equal parts of alcohol and water; filter and graduate. Or rub in a mortar, emplastrum plumbi of the Pharmacopœia with dry potassium carbonate, in the proportions of 150 to 40, or $3\frac{3}{4}$ to 1; lead carbonate and potassium oleate are formed; dissolve in rectified spirit, filter, and graduate.‡

Method of Graduation.—Take 50 C.C. of the *standard* solution of lime or baryta; put into the shaking bottle, and add to it slowly the soap solution from the finely graduated burette, shaking vigorously after each addition,

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* The soap solution here recommended was suggested by Assistant-Surgeon Nicholson, R.A., who has also given a complete system of analysis based on the soap test, "Chemical Journal," December 1862.

† MM. Boutron and Boudet, some years ago, made some modifications in the soap test manipulation, and their plan is now commonly followed in the French army, and is termed "Hydrotimetric." I am indebted to this plan for several adaptations.

‡ Redwood and Wood. By this plan a very pure and unalterable soap solution is obtained.

and placing the bottle on its side. When a thin beady lather, permanent for five minutes, is equally distributed over the whole surface, the process is complete. Read off the amount of soap solution used; if exactly 2·2 C.C. have been used, the process is correct; if less, the soap solution must be diluted with spirit. A simple rule will show how much spirit must be added. Suppose 1·6 C.C. have been used, and that the whole of the unused soap solution which has been made measures 210 C.C., then

$$\text{As } 1{\cdot}6 \ : \ 2{\cdot}2 \ :: \ 210 \ : \ x$$
$$x = 288{\cdot}7 \text{ C.C.}$$

The 210 C.C. must then be diluted with spirit and water to 288·7 C.C. The solution should then be tested once more to see that it is quite correct.

To avoid trouble, it is best always to make the soap solution too strong at first.

As the accuracy of all the subsequent processes depends on this graduation, it is necessary to take the greatest care in the operation.

In all cases the glasses, burettes, &c., must be perfectly clean; the least quantity of acid, for example, will destroy the accuracy of the process.

Rationale of the Process.—When an alkaline oleate is mixed with pure water, a lather is given almost immediately; but if lime, magnesia, iron, baryta, alumina, or other substances of this kind be present, oleates of these bases are formed, and no lather is given until the earthy bases are thrown down. Free (but not combined) carbonic acid prevents the lather. The soap combines in equivalent proportions with these bases, so that if the soap solution be graduated by a solution of known strength of any kind, it will be of equivalent strength for corresponding solutions of other bases. There are, however, one or two points which render the method less certain. One of these is, that, in the case of magnesia, there is a tendency to form double salts (Playfair and Campbell), so that the determination of magnesia is never so accurate as in the cases of lime or baryta. Carbonic acid appears to unite in equivalent proportions when it is passed through the soap solution; but if it be diffused in water, and then shaken up with the soap solution, two equivalents of the acid unite with one of soap.

It being clearly understood that the soap test is approximative (though really tolerably accurate if carefully used), it will be found an extremely convenient plan for medical men, as it demands very little time.

To avoid the repetition of the term tenth of a centimeter, it will be convenient to call each tenth of a centimeter one measure.

$\frac{1}{10}$ C.C. or 1 measure Soap solution equals in grammes	·00014 lime or ·0001 calcium.*
,, ,,	·0001 magnesia or ·00006 magnesium.
,, ,,	·0002 anhydrous sulphuric acid SO_3 or ·00024 SO_4.
,, ,,	·00025 calcium carbonate.
,, ,,	·00034 calcium sulphate.
,, ,,	·00021 magnesium carbonate.
,, ,,	·00022 carbonic acid CO_2 or ·0003 CO_3.
,, ,,	·000115 sodium.
,, ,,	·000195 potassium.
,, ,,	·000177 chlorine.
,, ,,	·00014 iron.
,,	

* The numbers of the metals as well as of the oxides are given, as the custom is becoming general of stating the amount of the metals themselves. So also the sulphuric acid may be stated as SO_4 (like chlorine) instead of SO_3; this also facilitates a calculation of combinations, if this is desired. For the same reason, the corresponding quantities of chlorine and sodium are given, for the convenience of calculation.

Processes with the Soap Test.

(*a.*) *Determination of the total Hardness of the Water.*—Take 50 C.C. of the filtered water; put it in a small stoppered bottle, and add the soap solution from the burette; shaking it strongly until a thin uniform beady lather spreads over the whole surface without any break. If the lather is permanent for five minutes, the process is complete; if it breaks before that time, add a drop or two more of the solution, and so proceed until a lather be obtained that is permanent for five minutes.

Then read off the number of measures of soap solution used.

From the total number of measures (or tenths of a centimeter) used, deduct two, as that amount is necessary to give a lather with the purest water, and this deduction has to be made in all the processes. The soap solution which has been used indicates the hardness due to all the ingredients which can act on it; in most drinking waters there are only lime and magnesian salts, iron, and free carbonic acid.

The amount of this total hardness is, for convenience, usually expressed in this country in the manner proposed by Dr Clark, *i.e.*, though dependent on various causes, it is expressed as equivalent to so much calcium carbonate per gallon, and in Clark's scale 1 grain of calcium carbonate per gallon is called 1 degree of hardness. Express the total hardness, therefore, in degrees of Clark's scale.

This is done as follows:—

Each 0·1 C.C., or in other words, each measure, of our soap solution, corresponds to ·00025 of calcium carbonate. Multiply, therefore, this co-efficient by the number of measures of soap solution used, and the result is the hardness of 50 C.C. of water expressed as calcium carbonate. Then, as we have acted on one-twentieth of a litre, multiply by 20 to give the amount per litre, and then by 70 to bring the amount of grains per gallon.

Example.—A lather was given with 5·2 C.C., or 52 measures of the soap solution. $(52-2) \times \cdot 00025 \times 20 \times 70 = 17 \cdot 5$ grains of calcium carbonate per gallon.

Hardness expressed as calcium carbonate $= 17^\circ \cdot 5$ Clark's scale

$$(\text{viz., } 1^\circ = 1 \text{ grain of } CaO\ CO_2 \text{ per gallon}).$$

The same result (viz., grains per gallon) is obtained if the number of measures (less 2) is multiplied by ·35; thus 52 measures were used

$$(52-2) \times \cdot 35 = 17 \cdot 5.$$

If the hardness of the water exceeds 80 measures of the soap solution, 25 C.C. of water only should be taken, and 25 C.C. of distilled water added. The result must then be multiplied by 2.

This process gives very valuable information as to the total amount of earthy bases. And, taken in connection with the next and with the qualitative examination, it will enable any one to say whether an objectionable amount of earthy salts exists in the water. The result just given is the total hardness, and this is again divided into the permanent and the removable.

The Permanent or Irremovable Hardness.—Boil a known quantity briskly for half an hour (one hour, Miller), and replace the loss by distilled water from time to time.

By boiling, all carbonic acid is driven off; all calcium carbonate, except about 2 grains per gallon, is thrown down; the calcium sulphate and chloride are not affected if the evaporation is not carried too far; the magnesium carbonate at first thrown down is redissolved as the water cools.

If iron is present, most of it is thrown down. When the water is cold, take 50 C.C. and determine hardness, and calculate it again for convenience in Clark's scale, *i.e.*, as equivalent to so many grains of calcium carbonate per gallon.

Example.—Before boiling, 52 measures, and after boiling 23 measures, of the soap solution, were used.

$$(23 - 2) \times \cdot 00025 \times 20 \times 70 = 7 \cdot 35 \text{ grains of calcium carbonate per gallon.}$$

Removable Hardness.—The difference between the total and the permanent hardness is the temporary or removable hardness, which in the example would be $17 \cdot 5 - 7 \cdot 35 = 10 \cdot 15$ grains of calcium carbonate per gallon.

The amount of permanent hardness is very important, as it chiefly represents the most objectionable earthy salts—viz., calcium sulphate and chloride, and the magnesian salts. The greater the permanent hardness, the worse is the water. The permanent hardness of a good water should not be greater than 3° or 4° of Clark's scale.

The determination, then, of

1. The total hardness,
2. The permanent or irremovable hardness,
3. The removable or temporary hardness,

will enable us to speak positively as to the hygienic characters of a water, as far as earthy salts are concerned.

(*b.*) *Determination of Certain Constituents by Soap.*—In many cases the analysis must end here; but it may be desirable to carry it farther, and to determine the amount of some ingredients: for example, lime, magnesia, sulphuric acid, carbonic acid.

An approximate estimate can be given of several of these ingredients by the soap test, which is sufficient for hygienic purposes; and any one who has learned to properly determine the hardness of a water, will be able to carry on the process into finer details.

Lime by the Soap Test.—Messrs Boutron and Boudet have proposed, after determination of total hardness, to precipitate the lime by ammonium oxalate, and then to determine the hardness again. The difference will be owing to lime removed. The difficulty here is to add enough, and not too much, of ammonium oxalate, which itself in excess gives hardness.

I have found the best way to perform this process is to have a perfectly concentrated clear solution of ammonium oxalate, and to add to 50 C.C. of water 1 drop for every 4 measures of soap solution used; then in other bottles, to add respectively, 1, 2, and 3 drops more. Then determine hardness of all the bottles, and select the result which gives the least hardness. In this way we can hit on the bottle which contains enough, but not too much ammonium oxalate. The water need not be filtered, but it should be allowed to stand at least for three or four hours, or, better still, twenty-four hours, before the hardness is taken.

Then multiply the difference between the total hardness and the hardness after the addition of the oxalate by the co-efficient for lime; this is ·00014, as each measure of the soap solution is equivalent to this amount of lime.

Example.—Total hardness,	. .	52
After lime precipitated,	.	10
Difference,	. .	42

$$42 \text{ measures} \times \cdot 00014 \times 20 \times 70 = 8 \cdot 232 \text{ grains of lime per gallon.}$$

Or, to save trouble, multiply the number of measures by ·196; the result is grains per gallon. If carefully done this result will be near the truth.

Magnesia by the Soap Test.—Boutron and Boudet propose to determine the magnesia by boiling the water from which the lime has been thrown down. All usual elements of hardness, except the magnesia, are thus got rid of. This is by no means so accurate a process as that of the lime; the lather is formed much less perfectly and sharply, and in addition the constitution of the magnesia and soap compound is variable. The result must be considered as quite approximative.

Take 200 C.C. of water; add to it the number of drops of solution of ammonium oxalate known to be sufficient by the lime experiment; allow to stand for twenty-four hours; filter, boil for half an hour, replace loss by distilled water; allow to cool in the vessel, which should be well corked, and determine hardness in 50 C.C.

As the lime has been thrown down and all iron removed, and carbonic acid driven off, the hardness is owing to magnesian salts of some kind.

Calculate as magnesia, the coefficient of which, for each degree of soap solution, is ·0001, or, as magnesium, the coefficient of which is ·00006.

Example.—Hardness, after driving off carbonic acid by boiling and precipitating lime, = 11.

$$(11 - 2) \times \cdot 0001 \times 20 \times 70 = 1 \cdot 26 \text{ grains of magnesia per gallon.}$$

Or, to save trouble, multiply the number of degrees by ·14; the result is grains per gallon.

Although this result is merely approximative, it is really nearer the truth than the determination by weighing in the hands of a beginner.

Sulphuric Acid by Soap Test.—This plan was proposed by Boutron and Boudet, and is briefly as follows:—The hardness of the water being known, 50 C.C. of the weak barytic solution are added to 50 C.C. of water, and the mixture is allowed to stand for 24 hours. The hardness (supposing no SO_3 were present) would be exactly equal to the original hardness of the water, and of the barytic solution, combined. But SO_3 being present, barium sulphate is precipitated, and there is a loss of hardness. Each degree of loss equals ·0002 of sulphuric acid (SO_3).

Example.—Original hardness, ...	62
50 C.C. barytic solution, ...	22
	84
After precipitation, ...	71·2
Difference, ...	12·8

$$\cdot 0002 \times 12 \cdot 8 \times 20 \times 70 = 3 \cdot 584 \text{ grains per gallon of } SO_3.$$

Usually this process gives good results. Occasionally, from some cause of which I am ignorant, the barium sulphate does not precipitate. This does not depend on the amount of sulphuric acid. The case with which this process is done renders it useful.

Free Carbonic Acid—Determination by the Soap Test.—In order to get rid of the fallacy from free carbonic acid acting on the soap. Clark recommended that the water should be well shaken in a bottle, so as to disengage some of the CO_2, and then that the air should be sucked out. But this does not entirely remove the carbonic acid.

By the soap test the free carbonic acid can be determined in the following way: Throw down all the lime carefully by ammonium oxalate, without add-

ing an excess, and determine the hardness in 50 C.C. as usual. The hardness will be owing to magnesian salts, iron, if it exists (or alumina or baryta in mineral waters), and carbonic acid. If, now, the water, freed from lime, be boiled, and the loss of water replaced by distilled water, the carbonic acid will be driven off. The hardness should be then again determined. The difference between the first and second trials will (if no iron still exist in the water) give the amount of soap solution which had been previously acted on by the carbonic acid.

Example.—1. Total magnesian and carbonic acid hardness, = 12 measures.
2. Magnesian hardness, ... = 7 „

Carbonic acid hardness, . . = 5 „

1 measure of soap sol. corresponds to ·00022 grammes carbonic acid. Therefore,

$$\cdot 00022 \times 5 \times 20 \times 70 = 1 \cdot 54 \text{ grains per gallon.}$$

As 2·116 cubic inches weigh one grain, multiply the number of grains by 2·116 to bring into cubic inches per gallon.

$$1 \cdot 54 \times 2 \cdot 116 = 3 \cdot 25 \text{ cubic inches.}$$

Or, to shorten the calculation, multiply the number of degrees of soap solution by ·65 ; the result is the amount of cubic inches per gallon.

$$5 \times \cdot 65 = 3 \cdot 25 \text{ cubic inches per gallon.*}$$

If much iron exists in the boiled water, it must be determined and its amount deducted: one measure of soap sol. corresponds to ·00014 grammes of iron (Fe).

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* Another process for carbonic acid in bicarbonates has been lately given by M. Lory (Chemical News, Oct. 9, 1868), and is as follows:—

1. Precipitate copper phosphate from the bichloride by sodium phosphate. Wash precipitate, suspend in water, and dissolve in slight excess of HCl, adding the acid drop by drop.
2. Dissolve ·265 grammes of pure dry sodium carbonate in 1 litre of water for a test solution, and pass through it a current of CO_2.
3. Take 100 C.C. of the test solution, and drop in the copper solution until the cloud first formed is redissolved. Read off amount of copper solution used, and dilute it if necessary, so that the 100 C.C. of test solution shall exactly take 4·4 C.C. of the copper solution. In testing water, take 100 C.C. and seize the exact moment of the disappearance of the cloud. Read off the amount of copper solution used, and calculate as follows:— 1 C.C. = ·006 of sodium carbonate, or ·00566 of calcium carbonate. To find the CO_2, multiply the C.C. used for 100 C.C. of water by ·5; the result is centigrammes of CO_2 per litre existing as bicarbonate.

Determination by Weight.

It may be desirable to determine these ingredients by weight, and the following processes can then be used:—

Lime by weight.—Take a known quantity of water; add ammonium oxalate, and then ammonia enough to give an ammoniacal smell. Allow precipitate thoroughly to subside, and then wash by decantation, or by throwing the precipitate on a small filter of Swedish paper, the weight of the ash of which is known. Decantation is recommended. If a filter is used, wash precipitate on filter; dry; scrape precipitate from filter, and place in a platinum crucible; burn filter to an ash, by holding it in a strong gas flame, and place it also in the crucible. Heat the crucible to gentle redness for fifteen minutes, moisten with a little water, and test with turmeric paper. If no reaction is given, the process is done. If the paper is browned (showing presence of caustic lime), recarbonate with ammonium carbonate, drive off excess of ammonia, dry, and weigh.

The substance weighed is calcium carbonate; multiply by ·56, and the result is lime.

Magnesia by weight.—Take the water from which the lime has been thrown down; evaporate to a small bulk; filter if there be turbidity; add solution of ammonium chloride and ammonia to slight excess; then add a solution of sodium phosphate; stir with a glass rod; set aside for twelve hours; throw precipitate on a filter, carefully detaching it from the sides of the glass; wash with ammoniacal water; dry; incinerate in an intense heat; weigh, taking care to deduct the ash of the filter known by previous experiment. The substance is magnesium pyrophosphate; multiply by ·36036 to get the amount of magnesia.

Sulphuric Acid by weight.—Take a known quantity of water (500 to 1000 C.C.); evaporate

Sub-Section II.—Microscopic Examination.

After the water has stood for twenty-four hours the sediment may be examined, or if there be much animal or vegetable life, a drop can at once be taken from the water. The larger animals can often be seen with the naked eye, by attentively looking through the glass when placed opposite a bright light.

In the sediment the chief microscopic appearances are—

1. Sand; easily known by its angles, and its being unaffected by any re-agent.
2. Clay and marl; amorphous non-angular particles, not acted on by re-agents.
3. Chalk; round and slightly angular particles, at once dissolved by acids.
4. Woody fibre; when much broken up, very little is seen beyond dark masses, sometimes rather fibrous looking; if less changed, and in large masses, unequivocal woody fibre can be seen.
5. Portions of leaves; bits of the veins, with occasionally some of the parenchyma, or dark masses without any distinguishing characters, are seen. If starchy matters remain, iodine detects them.
6. Algæ and confervoid growths are often seen even in tolerably pure waters, and portions of different water plants. Fine fungi may also be seen, with mycelium and spores.
7. In some cases remains of animals, epithelium, portions of muscular tissue, &c. In waters contaminated with sewage, an "ochreous substance" has been found by Hassall, and is considered to be altered muscular fibre tinged with bile. Nitric acid brings out the pink tint,* according to Hassall.
8. Infusoria.—The different kinds of paramecium are the most common, and are found in water containing both animal and vegetable organic matter. The *P. chrysalis* is very common in the Thames water (Hassall). Monads and rotifers are sometimes seen, and varieties of Actinophrys, *Euglena viridis*, &c.
9. Diatomaceæ in large numbers are found in some waters, and Hassall has figured a great number in the Thames water. *Gyrosigma hippocampus*, *Nitzschia elongata*, and species of Navicula are perhaps most common, but there is a considerable variety.
10. Entomostraca.—The water flea (*Daphnia pulex* and other varieties), (fig. 2), and the *Cyclops quadricornis* (male and female, fig. 3) are the most common, and are found in most stagnant waters. They are also found in some good waters, such as that of Manchester, which in summer is quite full of the Daphnia. The Cyclops also

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to a small bulk; acidify with hydrochloric acid, and add barium chloride; wash by decantation; dry and weigh. The substance is barium sulphate; multiply by ·34305 to get the amount of SO_3.

Silica and Iron.—Take the incinerated solids; add strong hydrochloric acid; evaporate to dryness; dissolve everything that will come away by repeated washing with hot water. Weigh remainder as silica and iron mixed.

Soda by weight.—The quantity of lime and magnesia must be known and calculated as sulphates; the silica and iron must also have been determined.

Take the total solids after their determination by evaporation; add cautiously dilute sulphuric acid, avoiding loss by spurting; warm gently for ten minutes; then evaporate to dryness; ignite, adding at the last a little ammonium carbonate; weigh.

The substance weighed is composed of silica and iron, and calcium, magnesium, and sodium sulphates. The weights of all the first-named substances being known, and deducted from the total weight, the residue is the weight of sodium sulphate. Multiply by ·43662; the result is soda (Na_2O).

* A microscopic Examination of the Water supplied to the Inhabitants of London. By Arthur Hill Hassall, M.D. 1850, p. 8.

is constantly found in water which is otherwise considered good. Many other entomostraca, as the Sida, Polyphemus, and less frequently the Moina, are also often seen.

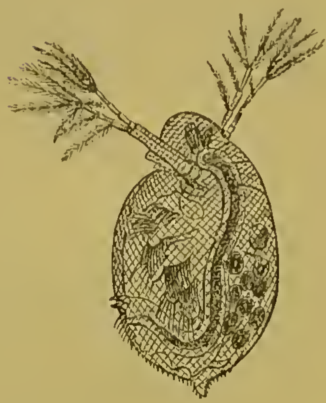


Fig. 2.

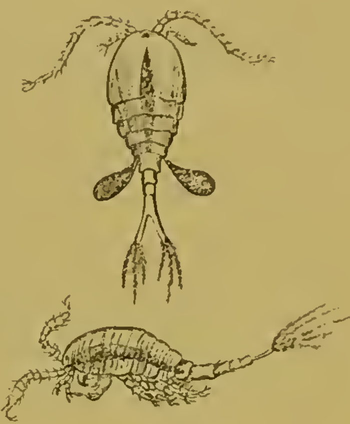


Fig. 3.

11. Annelids—Forms of Entozoa, ova in.—Small worms are not infrequently found in stagnant or marsh water, and sometimes in water contaminated with sewage.

The subjoined plates (kindly drawn for me by my friend Dr Maddox) show all that was found in the sediment of the water drawn from one of the wells at Netley, and the sediment of a ditch water, which may be taken to represent the usual surface water. Hassall has published numerous plates of the sediments in the waters of the London companies, which can be referred to.*

General Statement of the Results of the Examination of Water.

A table, showing the results of the physical, chemical, and microscopical examination, should be filled up as far as it can be in each case, and if the analyses of different waters could be uniformly stated, comparison and judgment would be much easier. The following form is suggested :—

WATER FROM

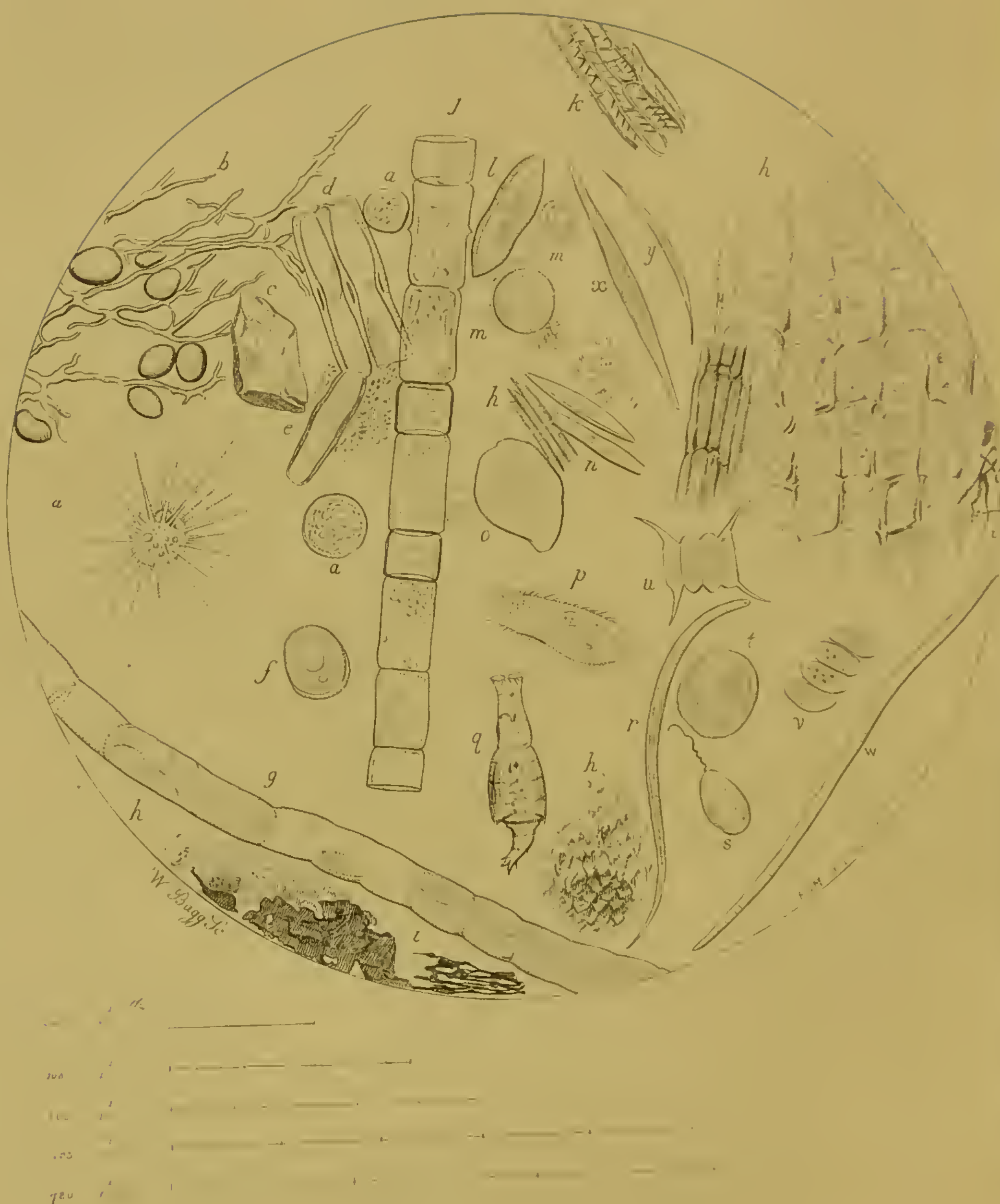
Examined 18

Grains per gallon †

1. PHYSICAL—
   - Colour in stratum of feet, ...
   - Transparency, ,, ...
   - Taste, ...
   - Smell, ...
2. CHEMICAL— . . . .
   - Suspended Matters—
     - Amount, ...
     - Nature, ...
   - Qualitative of dissolved matters—
     - (Statement as to much or little),
     - Reaction, ...
     - Organic matter by gold chloride, ...
     - Lime, ...
     - Magnesia, ...
     - Chlorine, ...
     - Sulphuric acid, ...

* *Op. cit.*

† Grammes or milligrammes per litre, or parts in 1000000, can of course be substituted at pleasure.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Description of Plate I.

Sediment from South wing Well, Netley, drawn with the Camera lucida *at the distance of* 10 *inches from the centre of eye-piece to paper.*

The presence of infusoria and animals of low type indicates the presence of organic matter, animal or vegetable, and it is therefore important to note their presence ; but it has not at present been shown that they are in themselves at all hurtful.

aaa Actinophrys Sol., early and complete stages, × 260.
b Supposed decomposing amœba-like expansions Gromio fluviatilis, × 435.
c Fragment of carbonate of lime, × 435.
d Navicula viridis, × 435.
e Grammatophora marina ? × 435.
f Supposed encysted stage of Euglena viridis, × 435.
g Pinnate conferva, × 780.
hhh Fragments of decaying vegetable matter, × 65.
ii Fragments of carbonaceous substance.
j Part of conferva filament, Conferva floccosa ? showing the various conditions of the protoplasm in the old and new cells, × 435.
k Part of leaf of Sphagnum or bog-moss, × 108.
l Grammatophora marina, × 435.
m Minute spores with zoospores ? × 435.
n Diatoma hyalinum, × 435.
o Cell with dividing protoplasm, × 435.
p Oxytricha lingua, × 260.
q Rotifer vulgaris, small, × 108.
r Anguillula fluviatilis, × 108.
s Peranema globosa, × 108.
t Statoblast of a fresh-water zoophyte ? × 108.
u Arthrodesmus incus, × 435.
v Minute Desmidiæ, Scenedesmus obtusus, × 780.
w Oscillaria lœvis, × 780.
x Homœocladia filiformis ? × 435.
y Ankistrodesmus falcatus, × 435.
z Minute moving particles, × 435.—(?) Zoospores.

(*To Binder—To face Plate I.*)

Description of Plate II.

Sediment of Ditch Water, drawn with the Camera lucida *at the distance of* 10 *inches from eye-piece to paper.*

a Decaying vegetable matter, cellular tissue, × 108.
b Pleurosigma formosum, before dividing, × 170.
c Oxytricha gibba, × 108.
d Amphileptus anser, × 170.
e Euglena viridis, × 285.
f Supposed urceola of some rotifer, × 108.
g Surirella gemma, × 108.
h Do. do. × 65.
i Foraminifera, × 65.
j Trachleocerca linguifera, × 65.
k Small Planaria? ovisacs distended, × 65.
l Navicula viridis, × 285.
m Paramecium aurelia, × 170.
n Coleps hirsutus, × 285.
o Pleuronema crassa, × 285.
p Monura dulcis, × 170.
q Surirella splendida, × 170.
r Biddulphia pulchella, × 285.
s Surirella striatula, × 170.
t Rotifer, Monolabis conica? × 108.
u Aregma, spore cases, × 285.
v Stentor ceruleus? do. *v.* × contracted, × 170.
w Trinema acinus? × 170.
x Pinnularia grandis, × 170.
y Gyrosigma angulatum before dividing, × 170.
z Alyscum saltans? × 170.
aa Synedra ulna, × 170.
bb Amphipora clata, × 285.
cc Gyrosigma Spencerii, × 285.
dd Nitzschia sigma, × 170.
ee Brachionus angularis, × 170.
ff Young Vorticella? × 170.
gg Gyrosigma fasciola, × 285.
hh Trachelius strictus, × 285.
ii Cocconema Boeckii, × 170.
jj Confervoid cell? with divided protoplasm, × 285.
kk Euplotes Charon, × 170.

(To Binder—To face Plate II.)


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× 250

Description of Plate III.

Drawing of Sediment in Thames Water, taken just above Teddington Lock, in April 1868. *Notice the evidence of impurities from men, viz., epithelium, woollen, cotton, and flax fibres.*

Fig. 1. Coleps hirsutus.
2. Bodo grandis.
3. Actinophrys Eichornii.
4. Epithelium (tessellated).
5. Leucophrys striata.
6. Anguillula fluviatilis.
7. Paramecium chrysalis, dividing (? sexual stage).
8. Vorticella microstoma.
9. Kerona, young?
10. Vorticella microstoma (stemless).
11. Paramecium aurelia.
12. Conferva.
13. Cocconema lanceolatum.
14. Synedra splendens.
15. Gyrosigma attenuatum.
16. Gomphonema acuminatum.
17. Wool fibre, dyed.
18. Cotton fibre, dyed.
19. Conferva floccosa.
20. Hair, barbed, of?
21. Kerona mytilus.
22. Siliceous spicule.
23. Diatome vulgare.
24. Fungi (? Torula).
25. Flax fibre.
26. Arthrodesmus quadricaudatus.
27. Stylonictria, ? histrio, dividing.
28. Paramecium caudatum.
29. Woody fibre, ? rootlets.
30. Pollen.
31. Vegetable tissue and mycelium, with spores.
32. Decaying vegetable matter.
33. Gomphonema curvatum.
34. Spores of Fungi (? Aregma).
35. Antherozoid of?
36. Encysted spore.

Decaying vegetable matter and infusoria abundant.

(To Binder—To face Plate III.)

WATER FROM —*continued.*

2. CHEMICAL—(*continued.*) Grains per gallon.

Qualitative—

- Phosphoric acid,
- Nitric acid,
- Nitrous acid,
- Ammonia,
- Iron,
- Sulphuretted hydrogen,
- Lead,

Quantitative—

- Total solids,
- Fireproof solids (after recarbonation),
- Destructible solids,
- Total oxygen required at a temp. of in presence of acid, by potassium permanganate,
- Oxygen for ferrous salts,
- ,, nitrous acid,
- ,, sulphuretted hydrogen,
- ,, other matters, presumably organic matter,
- Chlorine,
- Nitric acid (approximative),
- Ammonia before distillation,
- ,, in distillate from sodium carbonate,
- ,, in distillate from potassium permanganate,
- Total hardness,
- Permanent,
- Temporary,

State whether by soap test, or by weight.
- Calcium,
- Magnesium,
- Sulphuric acid (SO_4),
- Carbonic acid (combined, CO_3),

Aeration—

- Carbonic acid, in cubic inches,

3. MICROSCOPICAL.

Of course, in many cases only a certain number of these headings would be filled up; but the fact of others being left blank would be useful, as showing how far the examination had been carried. If the amount of sodium, potassium, silica, &c., be also determined, they can be placed afterwards. In this table no combination of acids and bases is attempted, but there is a simple statement of the experimental results.

SECTION IV.

SUB-SECTION I.—PURIFICATION OF WATER.

Without Filtration.

1. *Exposure to Air in divided currents.*—This was a plan proposed by Lind, for the water of the African west coast, more than 100 years ago, and frequently revived since. The water is simply poured through a sieve, or a tin or wooden plate, pierced with many small holes, so as to cause it to fall in finely divided streams, or a hand-pump is inserted in a cask of water, and the water is pumped up, and made to fall through perforated sheets of tin. It soon removes hydrosulphuric acid, offensive organic vapours, and, it is said, dissolved organic matter. The same plan has been used in Russia on a large scale; the water being allowed to fall down a series of steps, passing through wire gauze as it does so. In Paris, also, it has been employed on the small scale.

2. *Boiling and agitation.*—This plan gets rid of calcium carbonate, iron in part, and hydrosulphuric acid, and lessens, it is said, organic matter.

3. *Aluminous Salts.*—Alum has been used for centuries in India and China to purify water from suspended matters. It does this very effectually, if there be calcium carbonate in the water; calcium sulphate is found, and this and a bulky aluminium hydrate entangle the floating particles and sink to the bottom. Mr Alfred Bird has proposed aluminium tersulphate, which is equally efficacious; it is an acid liquid, containing about ·4 grains of the sulphate in each minim; and M. Bellamy* has also proposed a modification of the alum process, by adding additional potash to a solution of alum till the precipitate is redissolved. The quantity of crystallised alum to be used should be about 6 grains per gallon; of Mr Bird's fluid (sulphate of alumina), 20 drops.

From numerous experiments on purifications with crystallised alum, and with Mr Bird's patent liquid, I found the following effect to be produced, with and without calcium carbonate in the water:—

TABLE.

Effect on Artificial Sewage Water of different composition, the Sewage Matter being partly dissolved partly suspended.

	Volatile matter, per gallon.	Oxygen required to oxidise at 140° F., and in the presence of sulphuric acid, per gallon.
1. Distilled water, containing volatile sewage matter and 8 grains of calcium carbonate per gallon, ...	8·8	1·050
Same as above, after precipitating with 9 grains of crystallised alum per gallon, .	3·85	·350
Same, with 18 minims of Bird's patent liquid (aluminium sulphate), . .	4·20	·638
2. Distilled water, with sewage, but with only 2·1 grains calcium carbonate per gallon,	27·44	
Same as No. 2, with 18 minims of Bird's patent fluid, ...	23·8	
Same as No. 2, with 54 minims of Bird's patent fluid, ...	21·0	
3. Distilled water, without calcium carbonate, the sewage matter being almost entirely dissolved, and not suspended, .	5·	·805
Same, with 6·8 grains of crystallised alum,	4·76	·700
4. Same water as No. 3, but with 5 grains of calcium carbonate, . . .	5·	·805
Same, with 20 drops of Bird's liquid, .	4·02	·595
Same, with 6·8 grains of crystallised alum,	4·76	·595

It is clear, from these and other experiments, not only that calcium carbonate ought to be in the water, but that the action of both alum and Bird's fluid is made more upon the suspended organic matters than upon those actually dissolved; and, indeed, having regard to the great difficulty of ensuring that water is actually free from minute suspended matters, it is even a question whether aluminous salts will act in any appreciable degree on dis-

* Comptes Rendus de l'Acad. Nov. 11, 1867, p. 799.

solved organic matters. But on suspended matters, both organic and mineral, the effect is very great indeed. Common alum and Bird's liquid seemed to me practically equal; but alum, being solid, is more convenient for transport. If a sedimentous water is extremely soft, a little calcium chloride and sodium carbonate should be put in before the alum is added.

4. *Addition of Lime Water* (Clark's patent).—By combining with carbonic acid, it causes almost all the calcium carbonate previously and newly formed to be thrown down. It also throws down suspended and perhaps dissolved organic matters, and also, it is said, iron. It does not touch calcium and magnesium sulphate and chloride.

5. *Sodium Carbonate*, with boiling, throws down lime, and possibly a little lead, if present.

6. *Addition of Potassium or Sodium Permanganate* (Condy's red fluid).—I have made some experiments with pure Condy's fluid to determine the value of the permanganate. It certainly readily removes the smell of sulphuretted hydrogen and the peculiar offensive odour of impure water which has been kept in casks or tanks. If it forms a precipitate of manganic oxide, it also carries down suspended matters; but the formation of this precipitate is very uncertain. The action on the dissolved organic matters will of course vary with the nature of the substance; some of the organic matters, both animal and vegetable, will be oxidised;* but it will not in the cold act even upon the whole of these substances, and some organic matters are not touched. I have found a difficulty in estimating in figures the exact value of the permanganate even on oxidisable organic matters in solution, as when no precipitate falls, the amount of volatile substances, that is, of matters destructible by heat, is even increased by the oxidation.

One objection to the use of the permanganate is that it often communicates a yellow tint to the water, arising from suspended finely divided peroxide of manganese. This is probably of no moment as far as health is concerned, but it is unpleasant. Sometimes the addition of a little alum will carry down this suspended matter; boiling may be used, but often has no effect. Sometimes nothing removes it but charcoal filtration.

The indications for the use of permanganate are these. In the case of any foul-smelling or suspected water, add good Condy's fluid, teaspoonful by teaspoonful, to 3 or 4 gallons of the water, stirring constantly. When the least permanent pink tint is perceptible, stop for five minutes; if the tint is gone, add 36 drops, or, if necessary, 30 more, and then allow to stand for six hours; then add for each gallon 6 grains of a solution of crystallised alum, and, if the water is very soft, a little calcium chloride and sodium carbonate, and allow to stand for twelve or eighteen hours. If not clear, or if discoloured, filter through charcoal.

There are many cases in which this plan may be useful; and as the permanganate certainly removes smells and oxidises in the cold to some extent, it is a very good introduction to the alum process, and does work which alum alone will not do. But it cannot be considered a complete purifier of water from all organic matters.

Its oxidising power is, however, very useful in cleaning filters, as will be presently noted.

Use of the Strychnos potatorum.—In India the fruit of the *Strychnos potatorum* is used, especially by the better class of Hindoos, to purify water. It is beaten into a paste, and rubbed on the inside of the water jar or cask.

* I have not been able to satisfy myself that I could detect either nitric or nitrous acid after the treatment of dissolved sewage by permanganate; perhaps the amount formed is too small.

Dr Mouat informs me that it is chiefly used for the river water at the seasons when it is laden with silt, and that about 30 grains are used for 100 gallons of water, which act in twenty-four hours. Its action appears to be on suspended matters, which it possibly carries down by giving to the water a delicate albuminous coagulum, so that it purifies water on the same principle as beer is fined.* Dr O'Shaughnessy thought its action was connected with its astringency. I have made some experiments on its action, but without any satisfactory result. I did not even find it cleared the water thoroughly from suspended matters, and it had no effect on the amount of nitrous acid, ammonia, or of oxidisable organic matters, as far as these could be judged of by potassium permanganate. Renewed experiments are, however, necessary.

8. *Immersion of Iron Wire and Magnetic Oxide of Iron* (Medlock).—This plan is said to decompose organic matter. Charcoal and ferric oxide are sometimes mixed.

9. *Immersion or boiling of certain Vegetables*, especially those containing tannin; such as tea,† kino, the Laurier rose (*Nerium Oleander*, which is also rubbed on the inside of casks in Barbary), bitter almonds (in Egypt).

10. *Immersion of small pieces of Charcoal, and charring the inside of Casks.*—This is an extremely effectual plan, but the charcoal soon loses its power, and requires to be renewed. Berthollet considered that the charring of the casks was more effectual than the immersion; the charring can be renewed from time to time. Löwitz advises that a little sulphuric acid (10 drops to 1 lb. of charcoal) shall be added. A mixture of some of these substances has been used, as lime and alum (1 part to 2), or carbon and alum (4 parts to 1).

To put these facts in another form:—

Organic matter is got rid of most readily by exposure to air, boiling, agitation, charcoal, alum, potassium permanganate, astringents.

Carbonate of lime, by boiling and addition of caustic lime.

Sodium chloride, by filtration through a great depth of charcoal or sand.

Iron, by boiling and lime water, and in part by charcoal. Lead and copper, are also removed or lessened by pure charcoal.‡

Calcium and magnesium sulphate and chloride cannot be got rid of, but are perhaps lessened a little by filtration through charcoal.

It should also be remembered that some water plants have a purifying effect, apparently from the large quantity of oxygen they give out; and this takes place sometimes though the water itself is green.

With Filtration.

Sand and Gravel.—On the large scale, water is received into settling reservoirs, where the most bulky substances subside, and is then filtered through gravel and sand, either by descent or ascent, or both.§

The London water companies usually employ a depth of 3 to 5 feet; in

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* Pereira, Pharmaceutical Journal, vol. ix. p. 478.

† In the north of China, and especially during winter, the water of the Peiho becomes very impure, and contains not only suspended matters, but dissolved animal matter in large quantity, which gives the water a disagreeable offensive smell. The Chinese never drink it except as tea, which is cooled with a lump of ice, if it is desired to drink it cold. In this way they secure themselves from all bad effects of this water (Friedel, Das Klima Ost-Asiens, p. 60). The Europeans use alum and charcoal; but these do not always entirely remove the taste. The Tartars also use their "brick tea" to purify the water of the Steppes, which would otherwise be undrinkable.

‡ Chevalier, Traité des Désinfect. p. 147.

§ A good account of the engineering plans and filtration of the London Water Companies will be found in a work called "The Water Works of London," by Messrs Colburn & Shaw, 1867.

the latter case, the upper stratum of 18 inches or 2 feet is composed of sand, the lower 3 feet are made up of gravel, gradually increasing in coarseness from pieces the size of a small pea and bean to that of a middle-sized potato. A stratum of oyster shells, about 1½ inch in thickness, has been used by some companies instead of a layer of gravel, but this plan is not general. If the filter is 3 feet in thickness, the upper 15 inches are sand, and the lower 21 inches are gravel.

The pressure of water in these filters is not great; the depth of water is never above 2 feet, and some companies have only 1 foot; from 70 to 75 gallons is the usual quantity which should pass through in 24 hours for each square foot; but some companies filter more quickly, viz., at the rate of a gallon per 24 hours for each square inch, or 144 gallons per square foot.

The sand should not be too fine; the sharp angular particles are the best. The action seems chiefly, perhaps altogether, mechanical; the suspended impurities, both mineral and organic, rub upon and adhere to the angles and plane surfaces of the sand, which are gradually encrusted, and after a certain time, the sand has to be cleaned. The effect on suspended matters, both organic and mineral, is certainly satisfactory. On dissolved organic matters it is less so.* Mr Witt's experiments show only a removal of about 5 per cent. It is yet uncertain whether the action of sand on organic matter is at all chemical, *i.e.*, whether the organic matter is oxidised in its transit; considering what an amount of air is contained in the intensities of sand, and how finely the water is divided in its transit, some amount of oxidation is probable, but good chemical evidence is yet wanted. Mr Shield's experiments, given in the note, seem to me opposed to the probability of much chemical action. On dissolved mineral matters sand exerts at first, and when in thick layers, a good deal of action; much sodium chloride can be removed; and Professor Clark has stated that even lead can be got rid of by filtering through a thick stratum. Very finely divided clay seems to pass through more readily than any other suspended matters.

Instead of sand and gravel, trap rock has been used.

Animal Charcoal.—Pure animal charcoal (deprived of calcium phosphate and carbonate by washing or by hydrochloric acid) is now considered the best filtering material. The particles of charcoal should be well pressed together, and the passage of the water should not be too quick. Contact with the water for about four minutes appears about the best time.† There is a general agreement that there is a large removal of suspended matters, both mineral and organic; water even deeply tinged comes through a good charcoal filter very clear and bright. So also there seems no doubt that dissolved organic and mineral matters are also removed by charcoal in the first instance. All evidence agrees in respect of that point. But a serious difference of opinion exists as to the mode and permanence of action of animal charcoal.

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* In a sand and gravel filter, 33 inches in thickness, Mr Shield (Proc. Inst. of Civil Engineers for 1867) gives the following numbers:—The original amount of organic matter being ·8906 grains per gallon, the amount after filtration was as follows—after 23 hours' action, 1·012; after 120 hours, ·648; after 240 hours, ·917; after 376 hours, ·809. So that while, on the whole, the sand removed some organic matter, the amount was really inconsiderable.

† On this point there is some difference of opinion, as will be seen on reference to the debates on Mr Byrne's paper in the Proceedings of the Institution of Civil Engineers for 1867. Dr Letheby advocates a slow filtration, while Dr Frankland considers that a rapid flow is sufficient; on passing 41,000 gallons in one day through coarse charcoal, 3 feet in thickness, he found half the organic matter removed. With a head of 22½ feet of water he has passed, in 24 hours, as much as 90,734 gallons per square foot through 34 inches of charcoal; but in this case the purifying effect is not stated. Dr Frankland has, therefore, recommended that the water supply of a town shall be filtered through animal charcoal. The cost, however, would be large, though there is no doubt the water can be got through at a sufficient rate.

Thus, Mr Byrne* has shown that with a filter of charcoal weighing $4\frac{3}{4}$ lbs. through which 12 gallons of water (containing 10·8 grains of organic matter per gallon) were passed in 24 hours, the purifying effect was equal to a removal of $55\frac{1}{2}$ per cent. of the organic matters from the first gallon, but this gradually declined until at the fourth gallon only 1·33 per cent. was removed, and at the eighth gallon the action was reversed, and organic matter was given back to the water. Exception has been taken in two ways to this experiment—first, as regards the chemical proof of the organic matter, and secondly, as to the inference drawn from the experiment. As regards the first point, it appears to me difficult to set aside Mr Byrne's facts, and I think they must be accepted; as regards the second point, instead of the animal charcoal exciting no action, it might have been simply called on to do more than could be expected, for the purifying effect of no substance is inexhaustible.† This supposition does not appear probable, however, as only 43 grains of organic matter had gone through $4\frac{3}{4}$ lbs. of charcoal before the purifying power of the charcoal was virtually exhausted. The inference from Mr Byrne's experiments is supported by a statement by Mr Chapman,‡ who recovered from charcoal the amount of organic matter which had been previously removed by it from a water. This would almost seem to settle the point, were it not that there is strong and apparently indisputable evidence on the other side. In the debate on Mr Byrne's paper, both Dr Letheby and Dr Frankland brought forward facts to show that animal charcoal not merely arrests but chemically changes organic matter, and that this power is retained for a long time. Thus Dr Letheby obtained some charcoal which had been in use for two years, and through which it was calculated 292,000 gallons had passed. The charcoal still deprived water of colour and of organic matter, as judged of by permanganate and distillation with potash for ammonia. The charcoal being then analysed, gave the following results :—

4 ounces from top of filter	gave	·321	grains of	ammonia.
„ „ middle	„	·162	„	„
„ „ bottom	„	·240	„	„

The organic matter had not then accumulated; what had become of it? Water with organic matters having passed through this old charcoal, nitrites appeared in the filtrate. It had therefore been oxidised.

Dr Frankland's experiments were made on water containing small quantities of organic matter, but showed permanence of action after 5000 gallons had gone through.

Taking these experiments in connection with the older experiments of Witt, which showed a removal of 88 per cent. of organic matter, and with those of Gaultier de Claubry, and with the numerous experiments on char-

* Proceedings of the Institution of Civil Engineers for 1867.

† From experiments at Netley, conducted by Sergeant Sylvester of the Army Hospital Corps, it was found easy to exhaust charcoal by passing through a strong solution of organic matter, but the power was easily restored by cleansing the filter with a little potassium permanganate. The cessation of power must depend upon the relative amounts of the organic matter and charcoal, but the quantitative relations were not settled.

‡ Made in the debate on Mr Byrne's paper. See Proceedings of the Institution of Civil Engineers for 1867. Mr Shield's experiments on charcoal, the size of walnuts, recorded in the same debate, give the following results :—

	Original water.	After 67 hours.	After 91 hours.	After 115 hours.	After 139 hours.
Amount of organic matter,	1·430	·475	·478	·62	·971
Percentage removed,	...	66·78	68·	56·67	32·1

Charcoal in granules did not act quite so well.

coal filters, the reading of the facts seems to be that charcoal must have a chemical as well as a mechanical effect, but that the limits of purification are sooner reached than was supposed, if the organic matter be large, so that a more frequent cleansing is required. When, however, the amount of organic matter is small (under 1 or 2 grains per gallon), the action is very permanent. Dr Frankland has suggested that there may be two kinds of organic matter in water, one of which is not acted on by charcoal.

Vegetable and Peat Charcoal.—The effect of both these is decidedly inferior to animal charcoal* (Frankland and Byrne).

Domestic Filters.—On a small scale, a number of substances have been used, such as animal and vegetable charcoal made into blocks, or fine silica impregnated with charcoal (silicated carbon filters), hæmatite and magnetic iron ores, the so-called magnetic carbide, manganic oxide, flannel, wool, sponges, porous sandstones (natural and artificial), &c.

The Souchon filters, which are much employed in Paris, are made of diaphragms of wool, which is partially tanned by boiling in solution of alum and cream of tartar, then dyeing in infusion of gall-nuts, and washing in solution of sodium carbonate. The filter of M. Fouvielle, also used in Paris, is composed of nine layers of sponges, pounded sandstone, and gravel.

The best filters now in the market are made either of animal charcoal or of the so-called magnetic carbide of iron. I have examined a number of filters of this kind, but, for obvious reasons, I do not wish to give either the names of the makers or the tabular results. I found, however, that in most cases the action was very satisfactory. Suspended matters were almost entirely removed, and a considerable amount of dissolved organic matters was also taken out, and the action seemed to continue if no excessive impurity was used. Individual filters, even from the same maker, differ in their action; but on an average there is no charcoal or magnetic carbide filter now in the English market which cannot be relied on to remove 40 per cent. of dissolved organic matter, and in some cases it is much more;† the amount of nitrites, ammonia, and of hardness (chiefly carbonate of lime), is also lessened, and chloride of sodium is arrested by several filters to some extent. On the whole, a very useful purifying effect is produced even on dissolved matters, and it is hardly conceivable that, in the best charcoal or carbide domestic filters, any ova or even smaller living substance could pass through.

But there is a limit to all purifying powers, and the action of all filters is therefore temporary. After a time, which depends on the amount of impurity of the water, they become clogged; the substances which block them are organic matters (probably suspended) and lime salts. Sodium chloride, after being arrested for some time, may be given off again, and thus seldom long remains in a filter. Instead of taking the filters to pieces when they are clogged, the following plan may be resorted to:—Every two or three months (according to the kind of water) 4 to 6 ounces of the pharmacopœial solution of potassium permanganate, or 20 to 30 grains of the solid permanganate in a quart of distilled water, and 10 drops of strong sulphuric acid, should be poured through,‡ and, subsequently, a quarter to half an ounce of

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* Frankland, indeed, seems to consider wood charcoal useless. (Proceedings of Inst. of Civil Engineers, 1867.) Debate on Mr Byrne's paper.

† I examined six filters from one maker, and found the average removal of organic sewage matter to be 74·5 per cent.; the greatest being 96, and the least 56·2 per cent. The action was also fairly permanent, though cleansing was sometimes necessary.

‡ From experiments made at Netley by Sergeant Sylvester, of the Army Hospital Corps, it appears that the purifying effect of potassium permanganate in this way is very satisfactory, and the filter regains its power.

pure hydrochloric acid in 2 to 4 gallons of distilled water. This both aids the action of the permanganate, and assists in dissolving manganic oxide and calcium carbonate. Three gallons of distilled or good rain water should then be poured through, and the filter is fit again for use. This plan would be useful on foreign stations, where the filter cannot be sent home or taken to pieces; if it can be taken to pieces, the charcoal should be spread out in a thin layer, and exposed for some time to air and sun, or heated in an oven. If sponges are at all used, they should be removed from time to time, and thoroughly washed in hot water. If the filtering material is composed of a solid plate or ball, the surface should be brushed or scraped.

All kinds of charcoal, and, of course, most domestic filters, give off at first some substances to water; a certain amount of preliminary washing out with pure water is desirable.* Among other substances, calcium phosphate is taken up from animal charcoal, and even with a minute quantity the water will not act on lead (Frankland).

Small filters, as now sold in the market, may be divided into several kinds:—

1. Syphon cistern filters, which are placed in the water to be purified, and through which the water rises. The filter is often put in the cistern, and, of course, the delivery pipe always contains freshly filtered water.
2. Pipe filters, in which the filter is placed in the course of the delivery pipe; the effect is the same as with the syphon, but the flow may be quicker, as a greater pressure can be obtained. Both of these plans are very useful.
3. Common domestic filters, of various kinds, filled by hand.
4. Pocket filters, usually of the syphon kind, or made of a hollow block of charcoal, with a tube passing into the interior cavity, the water passes from without into the cavity (see page 61).

Sub-Section II.—Search after Water.

Occasionally a medical officer may be in a position in which he has to search for water. Few precise rules can be laid down.

On a plain, the depth at which water will be found will depend on the permeability of the soil, and the depth at which hard rock or clay will hold up water. The plain should be well surveyed; and if any part seems below the general level, a well should be sunk. The part most covered with herbage is likely to have the water nearest the surface. On a dry sandy plain, morning mists or swarms of insects are said sometimes to mark water below. Near the sea, water is generally found; even close to the sea it may be fresh, if a large body of fresh water flowing from higher ground holds back the salt water. But usually wells sunk near the sea are brackish; and it is necessary to sink several, passing farther and farther inland, till the point is reached where the fresh water has the predominance.

Among hills the search for water is easier. The hills store up water, which runs off into plains at their feet. Wells should be sunk at the foot of hills, not on a spur, but, if possible, at the lowest point; and if there are any indications of a water-course, as near there as possible. In the valleys among hills, the junction of two long valleys will, especially if there is any narrow-

* I have found that an interchange sometimes takes place in a filter. I passed some calcium sulphate and nitrate water through a new charcoal filter; the sulphuric acid was entirely removed, and the nitric acid partly so; their place was taken by phosphoric acid. It has occurred to to me whether a selenitic water might not be made more wholesome by thus substituting phosphoric acid, by leaving the calcium phosphate in the charcoal, or supplying it from time to time.

ing, generally give water. The outlet of the longest valleys should be chosen, and if there is any trace of the junction of two water-courses, the well should be sunk at their union. In a long valley with a contraction, water should be sought for on the mountain side of the contraction. In digging at the side of a valley, the side with the highest hills should be chosen.

Before commencing to dig, the country should be as carefully looked over as time and opportunity permit, and the dip of the strata made out, if possible. A little search will sometimes show which is the direction of fall from high grounds or a water-shed.

If moist ground only is reached, the insertion of a tube pierced with holes deep in the moist ground will sometimes cause a good deal of water to be collected. Norton's American tube well (page 7) gave satisfaction in Abyssinia. A common pump will raise the water in it if the depth be not more than 24 or 26 feet; if deeper, a special force pump has to be used.

Sub-Section III.—Special Considerations on the Supply of Water to Soldiers.

In barracks and hospitals, and in all usual stations, all that has to be done is to make periodical examinations of the quantity and quality of the water, to inspect the cisterns, &c., and to consider frequently if in any way wells or cisterns can have become contaminated. As far as possible, a record should be kept at each station of the normal composition of the water.

In transport ships, the water and the casks or tanks should always be examined before going to sea. Alum, charcoal, and potassium permanganate should be in store. If the water turns out bad, it must not at once be condemned; by aeration, boiling, charring the casks, throwing alum and charcoal into the water, what at first appeared a very unpromising water may be used. If it cannot be used, or if the water fails, distillation can always be managed. If the water distills over acid, neutralise with carbonate of soda. If there is a little taste from organic matter, let it be exposed to the air for two or three days. Sea water can be made potable by filtration through a great depth of charcoal if this can be obtained.

During marches, each soldier carries a water-bottle. He should be taught to refill it with good water whenever practicable; a little flannel bag, into which charcoal may be sewn, might be placed at the opening so as to strain the water. If the water is decidedly bad, it should be boiled with tea, and the cold tea drunk. The exhausted leaves, if well boiled in water, will give up a little more tannin and colouring matter, and will have a good effect; and if a soldier would do this after his evening meal, the water would be ready for the next day's march. Alum and charcoal should be used. Small charcoal or sandstone filters, with elastic tubes (fig. 4) at the top, which draw water through like siphons, or through which water can be sucked, are extremely useful, and are now much employed by officers. They have been largely used by the French soldiers in Algiers. The Austrian soldiers were formerly supplied with two boards pierced with holes, and with compressed sponges between them, and they poured their water through this. They also used sandstone and pumice-stones.

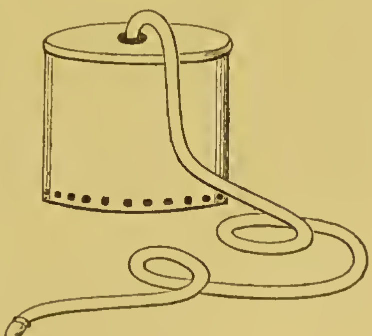

Fig. 4.

Soldiers should be taught that there is danger in drinking turbid water,

as they will often do when they are overcome with thirst. Not only all sorts of suspended matters may be gulped down, but even animals. On some occasions, the French army in Algiers has suffered from the men swallowing small leeches, which brought on dangerous bleeding. The leeches, which are so small as to look merely like small bits of vegetable matter, fix in the pharynx, the posterior nares, &c., more rarely in the larynx, causing repeated hæmoptysis, epistaxis, or asphyxia.

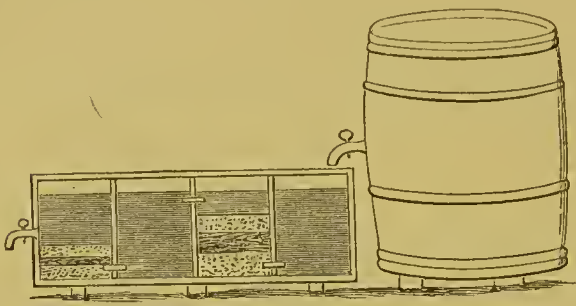

Fig. 5.

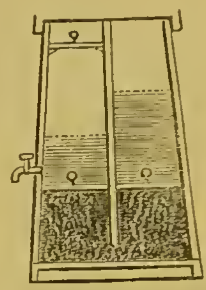

Fig. 6.

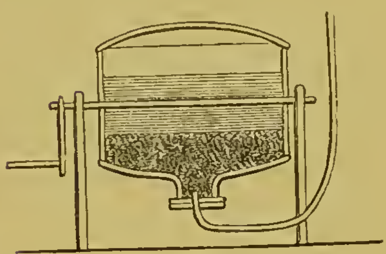

Fig. 7.

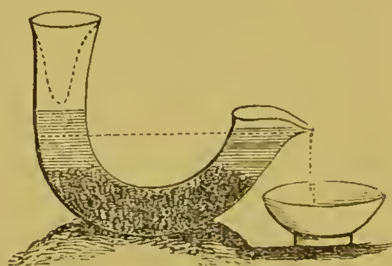

Fig. 8.

If water-carts or water-sacs are used, they should be regularly inspected; every cart should have a straining filter of sand, through which the water should pass. The carts and skins should be scrupulously clean. The water-carriers, or bheesties, in India should be paraded every morning, and the sources of water inquired into.

When halting ground is reached, it may be necessary to filter the water. A common plan is to carry a cask, charred inside, and pierced with small holes at the bottom; it is sunk in a small stream, and the water rises through the holes. A better plan still is to have two casks, one inside the other; the outer pierced with holes at the bottom, and the inner near the top; the space between is filled with sand, gravel, or charcoal, if procurable; the water rises through the gravel between the barrels, and flows into the inner. In the French army it is ordered* that, if other means cannot be procured, fresh and inodorous straw be taken, and chopped fine and pressed at the bottom of a tube pierced with holes; if possible, charcoal is to be intercalated among the straw. Great care must be taken to have the straw pure, and to change it often. Other simple plans are given in the drawings, which need little description. Figs. 5 and 6 speak for themselves. Fig. 7 is a barrel connected by a pipe with a supply above; the water rises through sand and charcoal,

* Code des Officiers de Santé. Par Didiot. P. 515.

and is drawn out above; the barrel is fixed on a winch, and the supply pipe being removed, and the hole closed, a few turns of the handle clear the sand. Fig. 8 is a simple contrivance, which may be made of wood or tin.

In the field, the medical officer may be sent on to give a report of the quantity and quality of any source.* Before the troops arrive he should make his arrangements for the different places of supply; men and cattle should be watered at different points; places should be assigned for washing; and if removal of excreta by water be attempted, the excreta should flow in far below any possible spring; in the case of a spring, several reservoirs of wood should be made, and the water allowed to flow from one to another—the highest for men, the second for cattle. If it is a running stream, localities should be fixed for the special purpose; that for the men's drinking-water should be highest up the stream, for animals below, washing lowest; sentries should be placed as soon as possible. The distribution of water should be regulated; streams are soon stirred up, made turbid, and the water becomes undrinkable for want, perhaps, of simple management.

Wherever practicable, the reservoirs or cisterns which are made should be covered in; even if it is merely the most flimsy covering, it is better than nothing.

In sieges, the same general rules must be attended to. The distribution of the water should be under the care of a vigilant medical officer. Advantage should be taken of every rainfall; fresh wells should be dug early; if necessary, distillation of brackish or sea water must be had recourse to.

SECTION V.

CONSEQUENCES OF AN INSUFFICIENT OR IMPURE SUPPLY OF WATER.

SUB-SECTION I.—INSUFFICIENT SUPPLY.

The consequences either of a short supply of water for domestic purposes, or of difficulty in removing water which has been used, are very similar. On this point much valuable information was collected by the Health of Towns Commission in their invaluable reports.† It was then shown that want of water leads to impurities of all kinds; the person and clothes are not washed, or are washed repeatedly in the same water; cooking water is used scantily, or more than once; habitations become dirty, streets are not cleaned, sewers become clogged; and in these various ways a want of water produces uncleanliness of the very air itself.

The result of such a state of things is a general lowered state of health among the population; it has been thought also that some skin diseases—scabies, and the epiphytic affections especially—and ophthalmia in some cases, are thus propagated. It has also appeared to me that the remarkable cessation of spotted typhus among the civilised and cleanly nations is in part owing, not merely to better ventilation, but to more frequent and thorough washing of clothes.

The deficiency of water leading to insufficient cleansing of sewers has a

* At Dr Marston's suggestion, I fitted out for Abyssinia a portable water-box, which could be carried without difficulty; it contained tubes, a spirit lamp and small flask, and four tests—acid silver nitrate, ammonium oxalate, gold chloride, and Nessler's solution.

† First and Second Reports (with evidence) of the Health of Towns Commission, 1844 and 1845.

great effect on the spread of typhoid and of choleraic diarrhœa; and cases have been known in which outbreaks of the latter disease have been arrested by a heavy fall of rain.

Little is known with certainty of the effects produced on men by deficiency in the supply of water. Under ordinary circumstances, the sensation of thirst, the most delicate and imperative of all our feelings, never permits any great deficiency for a long time, and the water-removing organs eliminate with wonderful rapidity any excess that may be taken, so as to keep the amount in the body within certain limits. But when circumstances prevent the supply of water, it is well known that the wish to drink becomes so great, that men will run any danger, or undergo any pain, in order to satisfy it. The exact bodily condition thus produced is not precisely known, but from experiments on animals and men, it would appear that a lessened amount of water in the body diminishes* the elimination of the pulmonary carbonic acid, the intestinal excreta, and all the important urinary excreta.

The more obvious effects produced on men who are deprived for some time of water is, besides the feeling of the most painful thirst, a great lowering of muscular strength and mental vigour. After a time, exertion becomes almost impossible, and it is wonderful to see what an extraordinary change is produced in an amazingly short time if water can be then procured. The supply of water becomes, then, a matter of the most urgent necessity when men are undergoing great muscular efforts, and it is very important that the supply should be by small quantities of water being frequently taken, and not by a large amount at any one time. The restriction of water by trainers is based on a misapprehension: a little water, and often, should be the rule. (See Exercise.)

Sub-Section II.—Impure Supply.

At present, owing probably to the difficulty of making analyses of waters, the exact connection between impure water and disease does not stand on so precise an experimental basis as might be wished. There are some persons who have denied that even considerable organic or mineral impurity can be proved to produce any bad effect; while others have believed that some mineral ingredients, such as calcium carbonate, are useful.

It may be true that water containing a large quantity of organic matter, or much calcium and magnesium sulphate, has been used for long periods without any ill effects. The water of the Canal de l'Ourcq, which contains much calcium bicarbonate, and some calcium and magnesium sulphate, was found by Parent-Duchâtelet to produce no bad effect, and Boudet has lately asserted the same thing.

In some of these cases, however, very little careful inquiry has been made into the state of health of those using the water, and that most fallacious of all evidence, a general impression, without a careful collection of facts, has often been the only ground on which the opinion has been come to. As well observed by Mr Simon, in one of his philosophical Reports,† we cannot expect to find the effect of impure water always sudden and violent; its results are indeed often gradual, and may elude ordinary observation, yet be not the less real and appreciable by a close inquiry. In fact, it is only when striking and violent effects are produced that public attention is arrested; the minor and more insidious, but not less certain, evils are borne with the

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* The experiments of Falck and Scheffer on animals, and of Mosler on men and women, are here referred to.

† Second Annual Report to the City of London, p. 121.

indifference and apathy of custom. In some cases it is by no means improbable that the use of the impure water, which is supposed to be innocuous, has been really restricted, or that experience has shown the necessity of purification in some way. This much seems to be certain, that as precise investigations proceed, and, indeed, in proportion to the care of the inquiry and the accuracy of the chemical examination, a continually increasing class of cases is found to be connected with the use of impure water, and it seems only reasonable to infer that a still more rigid inquiry will further prove the frequency and importance of this mode of origin of some diseases.

Animal organic matter, especially when of fæcal origin; vegetable organic matter, when derived from marshes; and some salts, are the principal noxious ingredients.*

Of the hurtful substances, the suspended animal, and especially fæcal matters, are probably the worst. At least, it is remarkable how frequently, both in outbreaks of diarrhœa and typhoid fever, the reports notice turbidity, discoloration, and smell of the water. It is this fact which makes the examination of colour and turbidity so important. The thoroughly dissolved organic matters appear less hurtful; at least there is some evidence that perfectly clear waters, though containing much matter dissipated by heat, and consisting of dissolved organic matter or its derivatives, are often taken without injury. Probably, also, the more recent the fæcal contamination, the more injurious, since the most poisonous attacks on record have been in cases of wells into which, after slow percolation for some time, a sudden gush of sewage water has taken place.

It has been frequently stated that the readily oxidisable organic matters in water are the most dangerous. This opinion has probably arisen from the idea that a substance in rapid chemical change is more likely to excite some corresponding and hurtful action in the body; and it may be true, but there is no evidence, to my knowledge, which can be trusted on the point. There is, on the other hand, some evidence that animal matters forming fatty acids, give rise to salts which, though not oxidising into nitrous and nitric acid, are as hurtful as the more oxidisable substances.

Of late years, too, an opinion has been expressed that the amount of the mineral substances is of little consequence. This can be true only in a limited sense; there are some mineral substances, such as sodium chloride, or carbonate, or calcium carbonate, which, within certain limits, appear to do no harm. But in the case of other minerals, such as calcium and magnesium sulphates and chlorides, and calcium nitrate, there can be little doubt that their use is injurious to many persons. It seems also probable that a combination of impurities, and especially the co-existence of organic matter and calcium sulphate, is hurtful; at least the analysis of waters which have decidedly produced injury, often shows that the impurities have been numerous.

As far as at present known, the existence of infusoria of different kinds is not hurtful, though they may indicate by their abundance the presence of organic impurity. The effect of algæ or fungi in drinking water is also a matter of which nothing is known, though it is very probable that future research may bring out something important in this direction.

The most practical way of stating the facts connected with the production of disease by water will be to enumerate the diseases which have been traced to the use of impure water, and to state the nature of the impurities.

* The quantities of those substances which should not be exceeded in good drinking water have been already given, as far as they can be stated at present.

1. AFFECTIONS OF THE ALIMENTARY MUCOUS MEMBRANE.

It is reasonable to suppose that the impurities of water would be likely to produce their greatest effect upon the membrane with which they come first in contact. This is in fact found to be the case.

Affections of the Stomach—Dyspepsia.

Symptoms which may be referred to the convenient term dyspepsia, and which consist in some loss of appetite, vague uneasiness or actual pain at the epigastrium, and slight nausea and constipation, with occasional diarrhœa, are caused by water containing a large quantity of calcium sulphate and chloride, and the magnesian salts. Dr Sutherland found the hard water of the red sandstone rocks, which was formerly much used in Liverpool, to have a decided effect in producing constipation, lessening the secretions, and causing visceral obstructions; and in Glasgow, the substitution of soft for hard water lessened, according to Dr Leech, the prevalence of dyspeptic complaints. It is a well-known fact that grooms object to give hard water to their horses, on the ground that it makes the coat staring and rough—a result which has been attributed to some derangement of digestion. The exact amount which will produce these symptoms has not been determined, but water containing more than 8 grains of each substance individually or collectively appears to be injurious to many persons. This would correspond to about 10 degrees of permanent hardness. A much less degree than this will affect some persons. In a well water at Chatham, which was found to disagree with so many persons that no one would use the water, the main ingredients were 19 grains of carbonate of lime, 11 grains of calcium sulphate, and 13 grains of sodium chloride per gallon. The total solids were 50 grains per gallon. In another case of the same kind, the total solids were 58 grains per gallon; the calcium carbonate was 22; the calcium sulphate 11, and the sodium chloride 14 grains per gallon.

Iron, in quantities sufficient to give a slight chalybeate taste, often produces slight dyspepsia, headache, and general malaise. Custom seems to partly remove these effects.

Diarrhœa.

Many conditions produce diarrhœa.

(*a.*) *Suspended Mineral Substances.*—Clay, marl—as in the cases of the water of the Mississippi, the Missouri, Rio Grande, Kansas,* of the Ganges, and many other rivers, will at certain times of the year produce diarrhœa, especially in persons unaccustomed to the water.

(*b.*) *Suspended Animal, and especially Fæcal Matters*, have produced diarrhœa in many cases; such water always contains dissolved organic matters, to which the effect may be partly owing. The case of Croydon in 1854 (Carpenter) is one of the most striking on record. In cases in which the water is largely contaminated with suspended sewage, it is important to observe that the symptoms are often markedly choleraic (purging, vomiting, cramps, and even some loss of heat). This point has been lately again noticed by Oldekop of Astrachan,† who found marked choleraic symptoms to be produced by the water of the Volga, which is impregnated with sewage.

Suspended animal and vegetable substances, washed off the ground by

* Hammond's Hygiene, p. 218. † Virchow's Archiv, band xxvi. p. 117.

heavy rain into shallow wells, often produco diarrhœa, as at Prague in 1860, when an endemie of "catarrh of the alimentary canal" was produeed by heavy floods washing impurities into the wells.*

(*c.*) *Suspended Vegetable Substances.*—In this eountry, and also in the late Ameriean civil war, several instances have oceurred of diarrhœa arising from the use of surface and ditch water, whieh ceased when wells were sunk; possibly there might be also animal contamination. It is not, therefore, quite eertain that suspended vegetable matter was the *vera causa.* Assistant-Surgeon Gore has reeorded a violent outbreak of diarrhœa at Bulama, on the west coast of Africa,† produced by the water of a well; the water was itself pure, but was milky from suspended matters, consisting of debris of plants, chlorophyll, minute eellular and branched algæ, monads, polygastriea, and minute particles of sand and clay. When filtered the water was quite harmless.

(*d.*) *Dissolved Animal Organic Matter.*—The opinion is very widely diffused that dissolved and putrescent animal organic matter, to the amount of 3 to 10 grains per gallon, may produce diarrhœa. This is possibly correct, but two points must be conceded—1*st*, That there are usually other impurities which aid the action of the organic matter; and 2*d*, That organic matter, even to the amount of 10 to 15 grains per gallon, may exist without bad effects, if it be perfectly dissolved. In the latter case the water is, however, always clear and sparkling, never tainted or discoloured. The frequent presence of other impurities renders it difficult to assign its exact influence to dissolved organic matters.

In the case of a well-ventilated court in Coventry,‡ where diarrhœa was constantly present, the water contained 5·68 grains per gallon of volatile and combustible matter, but then it contained also no less than 105 grains of fixed salts, which, as the water had a permanent hardness of 51°·6 (Clark's scale) after boiling, must have consisted of calcium and magnesium sulphates and chlorides. It also contained alkaline salts, nitrates, and ammonia. The composition was therefore so complex, that it is difficult to assign to tho organic matter its share in the effects.

The animal organic matter derived from graveyards appears to be espeeially hurtful; here also ammonium and calcium nitrites may be present.

(*e.*) *Dissolved Vegetable Matter.*—There is no evidence at present to show that this produces diarrhœa.

(*f.*) *Fœtid Gases.*—Water eontaining much sulphuretted hydrogen will give rise to diarrhœa, especially if organic matter be also present. In the late Mexican War (1861–62), the French troops suffered at Orizaba from a peeuliar dyspepsia and diarrhœa, attended with immense disengagement of gas and enormous eructations after meals. The erueted gas had a strong smell of sulphuretted hydrogen.§ This was traced to the use of water from sulphurous and alkaline springs; even the best waters of Orizaba eontained organic matter and ammonia in some quantity. The experiments of Professor Weber (see page 102) have shown what marked effeets are produced by the injeetion of sulphuretted hydrogen in solution in water into the blood; is it possible that water containing animal organic matter may oeeasionally form SH_2 after absorption into the blood, and that the poisonous effect of some water may be owing to this? The symptoms of poisoning by water contami-

* Canstatt's Jahresb. 1862, vol. ii. p. 31.

† Report on Hygiene by the Author, "Army Medical Report," vol. v. p. 423.

‡ Greenhow, in Second Report of the Medical Officer of the Privy Council, 1860, p. 75.

§ Poncet, in Rec. de Mém. de Méd. Mil. 1863, p. 218. The exact words are "une odeur d'acid sulfurique," but "sulf hydrique" must be meant.

nated by sewage are sometimes very like those noted by Weber in his experiments, viz., diarrhœa and even choleraic symptoms (lowering of temperature) and irritation of the lungs, spine, liver, and kidneys.

The absorption of sewer gases, as when the overflow-pipe of a cistern opens into the sewers, will cause diarrhœa. This seems perfectly proved by the case recorded by Dr Greenhow, in Mr Simon's second report.* All the conditions of an exact experiment seem to have been here fulfilled. In the gaol at Salford, two bodies of men, viz., the prisoners, 466 in number, and the officers and members of their families, 53 in number, were distributed throughout the gaol, and were under the same conditions of weather, lodgings, &c. Yet, of the former, 266, or 57 per cent., were attacked with sudden diarrhœa, of a choleraic type, while, of the latter body, not one was attacked, although, had the proportion been the same, 30 should have been taken ill. As the attack was remarkably sudden and evanescent, it was a case of poisoning of some kind. The cause was not in the air, for both classes were on a par in that respect; the food of the prisoners was examined, and was found to be good; the only other probable channel of the poisonous agent was the drinking water. It was discovered that, while the water was derived from the same source, the officers used the water of one cistern, and the prisoners' food was cooked with the water of another covered cistern, the untrapped overflow-pipe of which communicated with a common sewer. On the day of the outbreak this water was noticed to be less light, to have a yellow colour, and a somewhat unpleasant taste. Although the water was not further examined, there can be no doubt it was the cause of the attack, which ceased almost as rapidly as it commenced, on the cistern being emptied, and the pipe trapped.†

(*g.*) *Dissolved Mineral Matters*, if passing a certain point, produce diarrhœa. Boudin refers to an outbreak of diarrhœa at Oran, in Algiers, which was distinctly traced to bad water, and ceased on the cause being removed; the composition of the water is not explicitly given, but it contained lime, magnesia, and carbonate of soda. Sulphates of lime and magnesia also cause diarrhœa, following sometimes constipation. The selenitic well waters of Paris used to have this effect on strangers. Parent-Duchâtelet‡ noticed the constant excess of patients furnished by the prison of St Lazare, in consequence of diarrhœa, and he traced this to the water, which "contained a very large proportion of sulphate of lime and other purgative salts;" and he tells us that Pinel had noticed the same fact twenty years before in a particular section of the Salpêtrière. In some of the West Indian stations, the water drawn from the calcareous formation has been long abandoned, in consequence of the tendency to diarrhœa which it caused.

Nitrate of lime waters also produces diarrhœa. A case is on record, in which a well water was obliged to be disused, in consequence of its impregnation with butyrate of lime (105 grains per gallon), which was derived from a trench filled with decomposing animal and vegetable matters. Both men and beasts were affected with diarrhœa from its use.§

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* Second Report of the Medical Officer of the Privy Council, Parl. Paper, 1860, p. 153.

† The period of the incubation, so to speak, of the attack of diarrhœa is well shown in this case. Granting that the cause was only acting on the day of the outbreak, the following numbers come out:—Out of 100 sick

73·68 per cent.	fell sick within 24 hours.	
21·02 ,,	,, in the second	24 hours.
2·63 ,,	,, ,, third	,,
1·87 ,,	,, ,, fourth	,,
0·75 ,,	,, ,, fifth	,,

The rapidity with which this cause of disease always seems to act is very remarkable.

‡ Hygiène Publique, t. i. p. 236.

§ Zeitschrift für Hygiene, vol. i. p. 166. See also a remark on the effect of calcium and

Brackish water (whether rendered so by the sea, or derived from loose sands) produces diarrhœa in a large percentage of persons, and at some of the Cape frontier stations water of this character formerly caused much disease of this kind. In a water I examined, which became brackish from sea water, and which produced diarrhœa in almost all persons, I found the amount of chloride of sodium to be 253 grains per gallon. But, doubtless, a much less quantity than this, especially if chloride of magnesium be present, will act in this way.

(*h*.) *Metallic Impregnation.*—Occasionally animal organic matter acts in an indirect way, by producing nitrites and nitrates, which act on metals.

Dr Bædeker,* a physician in Witten, was called to some cases of sickness produced, apparently, by water. On examining the point, he found the water was drawn from a pump with a copper cylinder, and contained a considerable quantity of copper, which seemed to be in combination with some organic matter.

Lead (as might have been anticipated) was also largely present in this water, as leaden pumps were used; iron, on the contrary, was not dissolved.

Dysentery.

Dysentery also is decidedly produced by impure water, and this cause ranks high in the etiology of dysentery, though perhaps it is not the first.

Several of the older army-surgeons refer to this cause. Pringle does so several times, and Donald Monro, in the Campaigns in Flanders and Germany. In the West Indies, Lemprière,† in 1799, noticed the increase of bowel complaints in Jamaica in May, when, after floods, the water was bad and turbid, "and loaded with dirt and filth." He also mentions, that at Kingston and Port Royal the dysentery was owing to brackish water. It was not, however, for many years after this that fresh sources of water were sought for in the West Indies, and that rain water began to be used when good spring or river water could not be got.

Davis‡ mentions as a curious fact, in reference to the West Indies, that ships' crews, when ordered to Tortola, were "invariably seized with fluxes," which were caused by the water. But the inhabitants who used tank (*i.e.*, rain) water were free; and so well known was this, that when any resident at Tortola was invited to dinner on board a man-of-war, it was no unusual thing for him to carry his drinking water with him.

The dysentery at Walcheren, in 1809, was in no small degree owing to the bad water, which was almost everywhere brackish.

The epidemic at Guadaloupe, in 1847, recorded by Cornuel, seems also quite conclusive as to the effect of impure water in causing, not merely isolated cases, but a wide-spread outbreak.§

In 1860, at Prague, there were many cases of dysentery, clearly traced to the use of water of wells and springs rendered foul by substances washed into the water by heavy floods. Exact analyses were not made.

On the West Coast of Africa (Cape Coast Castle), an attack of dysentery was traced by Assistant-Surgeon Oakes to the passage of sewage from a cesspool into one of the tanks. "This was remedied, and the result was the almost total disappearance of the disease."

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potassium nitrate in causing a tendency to diarrhœa in the Report on the Drainage of Berlin (Die Kanalisation von Berlin, 1868, pp. 27, 28).

* Pappenheim's Beiträge, heft iv. p. 49.

† Vol. i. p. 25.

‡ On the Walcheren Fever, p. 10.

§ See a review by the author on Dysentery, in the "British and Foreign Medical and Chirurgical Review" for 1847, for fuller details of this epidemic.

That in the East Indies a great deal of dysentery has been produced by impure water, is a matter too familiar almost to be mentioned (Annesley; Twining). Its constant prevalence at Secunderabad, in the Deccan, appears to have been partly owing to the water which percolated through a large graveyard. One of the sources of water contained 119 grains of solids per gallon, and in some instances there were 8, 11, and even 30 grains per gallon of organic matter. (*Indian Report*, p. 44.)

The great effect produced by the impure water of Calcutta in this way has been lately pointed out by Chevers. (*Indian Annals*, No. 17, p. 70, 1864.)

In time of war this cause has often been present; and the great loss by dysentery in the Peninsula, at Ciudad Rodrigo, was partly attributed by Sir J. M'Grigor to the use of water passing through a cemetery where nearly 20,000 bodies had been hastily interred.

The impurities which thus produce dysentery appear to be of the same kind as those which cause the allied condition, diarrhœa. Suspended earthy matters, suspended animal organic matter, calcium and magnesium sulphates and chlorides, calcium and ammonium nitrates, large quantities of sodium and magnesium chlorides in solution, appear to be the usual ingredients; but there are few perfect analyses yet known.

The observations which prove so satisfactorily that the dysenteric stools can propagate the disease, make it probable that, as in the case of typhoid fever and cholera, the accidental passage of dysenteric evacuations into drinking water may have some share in spreading the disease.

2. AFFECTION OF OTHER MUCOUS MEMBRANES BESIDES THE ALIMENTARY.

Little has yet been done to trace out this point. At Prague, after the severe flood of 1860, bronchial catarrh was frequent, probably caused chiefly by the chills arising from the great evaporation; but it was noticed that bronchial catarrh was most common when the drinking water was foulest and produced dysentery. Possibly the bronchial and the urinary mucous membranes may also suffer from foul water; the point is well worthy of close investigation.

3. SPECIFIC DISEASES.

That some of the specificc diseases are disseminated by drinking water is a fact which has only attracted its due share of attention of late years. It is certainly one of the most important steps in Etiology which has been made in this century.

Malarious Fevers.

Hippocrates states that the spleens of those who drink the water of marshes become enlarged and hard; and Rhazes not only asserted this, but affirmed that it generated fevers. Little attention seems to have been paid to this remark, and in modern times the opinions of Lancisi, that the air of marshes is the sole cause of intermittents, has been so generally adopted, that the possibility of the introduction of the cause by means of water, as well as air, was overlooked. Still it has been a very general belief among the inhabitants of marshy countries, that the water could produce fever. Henry Marshall* says that the Singhalese attribute fevers to impure water, "especially if elephants or buffaloes have been washing in it," and it is to be presumed that he referred to periodical fevers. On making some inquiries of the in-

* Topography of Ceylon, p. 52.

habitants of the highly malarious plains of Troy, during the Crimean war, I found the villagers universally stated, that those who drank marsh water had fever at all times of the year, while those who drank pure water, only got ague during the late summer and autumnal months. The same belief is prevalent in the south of India, and in Western Candeish, Canara, Balaghut and Mysore, and in the deadly Wynaad district, it is stated by Mr Bettington of the Madras Civil Service, that it "is notorious that the water produces fever and affections of the spleen." The Essay by this gentleman* gives, indeed, some extremely strong evidence on this point. He refers to villages placed under the same conditions as to marsh air, but in some of which fevers are prevalent, in others not; the only difference is, that the latter are supplied with pure water, the former with marsh or nullah water full of vegetable debris. In one village there are two sources of supply,—a tank fed by surface and marsh water and a spring; those only who drink the tank water get fever. In a village (Tulliwaree) no one used to escape the fever; Mr Bettington dug a well, the fever disappeared, and, in the last fourteen years, has not returned.

Another village (Tambatz) was also "notoriously unhealthy," a well was dug, and the inhabitants became healthy. Nothing can well be stronger than the positive and negative evidence brought forward in this paper.

Dr Moore (Indian Annals, 1867) has also noted his opinion of malarious disease being thus produced; and M. Commaille has lately (Rec. de Mém. de Méd. Mil. Nov. 1868, p. 427) stated, that in Marseilles paroxysmal fevers, formerly unknown, have made their appearance, since the supply to the city has been taken from the canal of Marseilles.

In the "Landes" (of south-west France), the water from the extensive sandy plain contains much vegetable matter, obtained from the vegetable deposit, which binds together the siliceous particles of the subsoil. It has a marshy smell, and, according to Fauré, produces intermittent and visceral engorgements.

The same facts have been noticed in this country. Twenty years ago Mr Blower of Bedford mentioned a case in which the ague of a village had been much lessened by digging wells, and he refers to an instance in which, in the parish of Houghton, almost the only family which escaped ague at one time was that of a farmer who used well water, while all the other persons drank ditch water.†

At Sheerness the use of the ditch water, which is highly impure with vegetable debris, has been also considered to be one of the chief causes of the extraordinary insalubrity.‡

At Versailles a sudden attack of ague in a regiment of cavalry was traced to the use of surface water taken from a marshy district.§

The case of the Argo, recorded by Boudin,|| is an extremely strong one. In 1834, 800 soldiers in good health embarked in three vessels to pass from Bona in Algiers to Marseilles. They all arrived at Marseilles the same day. In two vessels there were 680 men without a single sick man. In the third vessel, the Argo, there had been 120 men; thirteen died during the short passage (time not given), and of the 107 survivors no less than 98 were dis-

* Indian Annals, 1856, p. 526.

† Snow "On the Mode of Communication of Cholera." 2d edit. 1855, p. 130.

‡ Is it not possible that the great decline of agues in England is partly due to a purer drinking water being now used? Formerly, there can be little doubt, when there was no organised supply, and much fewer wells existed, the people must have taken their supply from surface collections and ditches, as they do now, or did till lately, at Sheerness.

§ Grainger's Report on Cholera. Appendix (B), page 95; footnote.

|| Traité de Géographie et de Statistique Médicales, 1857, t. i. p. 142.

embarked with all forms of paludal fevers, and as Boudin himself saw the men, there was no doubt of the diagnosis. The crew of the Argo had not a single sick man.

All the soldiers had been exposed to the same influences of atmosphere before embarkation. The crew and the soldiers of the Argo were exposed to the same atmospheric condition during the voyage; the influence of air seems therefore excluded. There is no notice of the food, but the production of malarious fever from food has never been suggested. The water was, however, different—in the two healthy ships the water was good. The soldiers on board the Argo had been supplied with water from a marsh, which had a disagreeable taste and odour; the crew of the Argo had pure water. The evidence seems here as nearly complete as could be wished.

One very important circumstance is the rapidity of development of the malarious disease and its fatality when introduced in water. It is the same thing as in the case of diarrhœa and dysentery. Either the fever-making cause must be in larger quantity in the water, or, what is equally probable, must be more readily taken up into the circulation and carried to the spleen, than when the cause enters by the lungs.

In opposition, however, to all these statements must be placed a remark of Finke's,* that in Hungary and Holland marsh water is daily taken without injury. But in Hungary, Dr Grosz states that, to avoid the injurious effects of the marsh water, it is customary to mix brandy with it, "a custom which favours hypertrophies of the inner organs."†

Typhoid Fever.

The belief that typhoid fever can spread by means of water as well as air appears to be quite of modern origin, though some epidemics, such as the "Schleim-fieber" of Göttingen in 1760, were attributed in part to the use of impure water. In 1822, Walz affirmed that an outbreak of "typhus" (typhoid) at Saarlouis, in Rhenish Prussia, was caused by impure water; and in 1843, Müller discovered that 129 cases of typhus abdominalis (typhoid), and 21 deaths which occurred in the garrison at Mayence, were produced by fæcal matter passing into the drinking water, which had a disagreeable putrid smell. In 1848, E. A. W. Richter published an account of an outbreak of the same kind which occurred in a school at Vienna, from the contents of a sewer passing into the drinking water.‡ In 1852, Dr Austin Flint§ published the particulars of a similar outbreak of typhoid fever at the hamlet of North Boston (Erie, U.S.) in 1843.

In 1852–53, a severe outbreak of typhoid fever took place at Croydon, and was thoroughly investigated by many competent observers; and it was shown by Mr Carpenter of Croydon that it was partly, at any rate, spread by the pollution of the drinking water from the contents of cesspools.

In 1856, Dr Routh‖ published a case in which the evacuations of a typhoid patient were thrown into a closet, the pipe of which passed directly into the cistern of the drinking water, in a well-ventilated house at Hastings. No less than eight persons were affected with more or less typhodial symptoms; many of these had not been brought into any personal contact with the sick person.

* Oesterlen's Handb. der Hygiene. 2d edit. 1857, p. 129; footnote.
† Quoted by Wutzer, Reise in den Orient. Europas, band i. p. 101.
‡ All these cases are related by Riecke in his excellent work "Der Kreigs und Friedens-Typhus." Nordhausen, 1850, pp. 44–58.
§ Clinical Reports on Continued Fever. By Austin Flint, M.D. Buffalo, 1852, p. 380.
‖ Fæcal Fermentation as a Cause of Disease. Pamphlet. Lond. 1856, p. 34.

In 1859, Dr W. Budd* published two very conclusive cases, in which well water was contaminated by sewage.

There is no satisfactory evidence that typhoid stools had been in the sewage matter, but their presence is not excluded. I learn, from personal communication with Dr Budd, that he has long been convinced of the *occasional* propagation of typhoid fever in this way.

In 1860, an outbreak of typhoid fever occurred at the Convent of Sisters of Charity at Munich. 31 persons out of 120 were attacked between the 15th September and the 4th of October, with severe illness, and 14 of these cases were true typhoid; 4 died. The cause was traced to wells impregnated with much organic matter (and among other things typhoid dejections), and containing nitrates and lime. On the cessation of the use of this water, the fever ceased.†

The propagation of typhoid fever in Bedford would certainly appear, from Mr Simon's report,‡ to have been partly through the medium of the water.

Dr Schmitt§ has for several years paid particular attention to this point, and in 1861 published several very striking cases.

A case bearing on the same point was brought before the Metropolitan Officers of Health in 1862,‖ by Mr Wilkinson of Sydenham. In this case the water was contaminated by absorption of sewer gases.

In 1862, a very sudden and severe outbreak of typhoid in a barrack at Munich was traced to water impregnated with fæcal matter; on ceasing to use the water, the disease disappeared.¶ In 1865 a very remarkable outbreak of typhoid occurred at Ratho, in Scotland, and was traced to drinking water contaminated with sewage.** In 1866 typhoid fever broke out in a girls' school at Bishopstoke, near Southampton, and was traced unequivocally to the bursting of a sewer pipe into the well. The water was disagreeable both to smell and taste. 17 or 18 persons were affected out of 26 or 28. Several very striking instances are recorded in Mr Simon's Reports for 1866 and 1867, by Drs Seaton, Buchanan, and Thorne,†† and in some of these cases analyses of the water were made, which showed it to be impure, and to contain organic sewage, or its derivatives. A very good case, at the Garnkirk works in Glasgow, is recorded by Dr Percy.‡‡

That water may be the medium of propagating typhoid, thus seems to be proved by sufficient evidence; and it has been admitted by men who have paid special attention to this subject, as Jenner, W. Budd, and Simon. It does not seem unlikely, indeed, that this mode of spreading will be found to be far more common than is supposed.

Two questions arise in connection with this subject—

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* Lancet, Oct. 29, 1859, p. 432.

† Edinburgh Medical Journal, Jan. 1862, p. 1153. See also Gietl, Die Ursachen des Enter. Typhus in München, 1865, p. 58.

‡ Third Report of the Medical Officer of the Privy Council, 1860.

§ Journ. de Méd. de Bruxelles, Sept. 1861; and Canstatt's Jahresb. for 1861, band iv. pp. 182, 183. See the 2d edition of this work for a short account of them.

‖ British Medical Journal, March 1, 1862.

¶ Gietl, Die Ursachen des Ent. Typhus in München, 1865, p. 62. In this little book is much evidence to show the propagation of typhoid by foul water and by deficient arrangements for removal of excreta, as well as many instances of the carrying of the disease from place to place, analogous to those narrated by Bretonneau many years ago.

** Edin. Med. Journ. Dec. 1865. In this case a groom came to the house ill with typhoid from Dundee, and thus introduced the disease. This fact was communicated to me by a relation of the owner of the house.

†† Dr Seaton's Report on Tottenham (Report of Medical Officer to the Privy Council for 1866, p. 215). Dr Buchanan on Guildford (Ibid. for 1867, p. 34); and Dr Thorne's Report on Testing (Ibid. p. 41). In all these instances the evidence reaches the highest degree of probability, and in the cases of Guildford of almost absolute certainty.

‡‡ Lancet, June 1868.

1. As typhoid fever undoubtedly spreads also through the air, What is the proportion of cases disseminated by water, as compared with those disseminated by air? No answer can yet be given to this question.

There is one point of some interest. When the dates of attacks are given, it is curious to observe how short the incubative period appears to be; while it is probable that it takes many days (8 to 14) after the typhoid poison has entered with the air before the early malaise comes on, in some of the cases of typhoid brought on by water, two or three days only elapse before the symptoms are marked.*

A very large proportion also of the susceptible persons who drink the water is affected.

2. Will decomposing sewage in water produce typhoid fever, or must the evacuations of a typhoid patient pass in? This is part of the larger question of the origin and propagation of specific poisons. It is certainly remarkable, in the range of cases recorded by Schmitt, how uniformly the possibility of the passage of typhoid stools is disregarded. Everything is attributed to fæcal matters merely. But this may have been an oversight. The opinion that the stools of typhoid are the especial carriers of the poison was first, I believe, explicitly stated by Canstatt,† and has been also ably argued by W. Budd. Whether or not the special putrefactive change going on in these evacuations can be communicated to other organic matter out of the body, is not certain; but it is probable that in the body it must meet with a fit nidus, such as the Peyerian glands of a young person, before it can act.

Cholera.

Few of the earlier investigators of cholera appear to have imagined that the specific poison might find entrance by the means of drinking water. There is an intimation of the kind in a remark by Dr Müller;‡ and Jameson, in the Bengal Report of 1820, alludes to the effect of impure water, but in a cursory way.

In 1849, the late Dr Snow, in investigating some circumscribed outbreaks of cholera in Horsleydown, Wandsworth, and other places, came to the conclusion that, in these instances, the disease arose from cholera evacuations finding their way into the drinking water. Judging from the light of subsequent experience, it now seems extremely probable that this was the case, and to Dr Snow must certainly be attributed the very great merit of discovering this most important fact. At first, certainly the evidence was defective,§ but gradually fresh instances were collected, and in 1854 occurred the celebrated

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* Dr W. Budd says, in a letter to me—"In the cases in which the poison is conveyed by water, infection seems to be much more certain: and I have reason to think that the period of incubation is materially shortened. An illustration of this seems to be furnished by the memorable outbreak which occurred at Cowbridge some years ago, and which presented this unexampled fact: that out of some 90 or 100 persons who went to a race ball at the principal inn there, more than one-third were within a short time laid up with the fever. In this case, there was satisfactory reason to think that the water was contaminated, though there was no chemical examination." In the attack at Guildford, however, the incubative period was not shortened, as Dr Buchanan calculates it at 11 days.

† "Wahrscheinlich sind die Exhalationen des Krankes, seine Excremente, *vielleicht die typhösen Aftergebilde im Darme*, die Träger des Contagiums."—Canstatt, *Spec. Path. und Ther.* 2d edit. band ii. p. 572 (1847).

‡ Einige Bemerkungen über die Asiat. Cholera. Hannover, 1848, p. 36.

§ There seemed at once an *a priori* argument adverse to this view. as, at that time, all evidence was against the idea of cholera evacuations being capable of causing the disease. They had been tasted and drank (in 1832) by men, and been given to animals, without effect. Persons inoculated themselves in dissections constantly, and bathed their hands in the fluids of the intestines; in India the pariahs who remove excreta, and everywhere the washerwomen who washed the clothes of the sick, did not especially suffer. And to these arguments must be

instance of the Broad Street pump in London, which was investigated by a committee, whose report, drawn up by Mr John Marshall, of University College, with great logical power, contains the most convincing evidence that, in that instance, at any rate, the poison of cholera found its way into the body through the drinking water.*

In 1855, Dr Snow published a second edition of his book, giving an account of all the cases hitherto known, and adding some evidence also as to the introduction in this way of other specific poisons.†

The facts, at present, may be briefly summed up as follows :—

1. Local outbreaks, in which contamination of the drinking water was either proved or in which the evidence of the origin and succession of cases seemed to make it certain that the cause was in the drinking water. In England, Dr Snow and others have thus recorded cases occurring in 1849 and 1854 at Horsleydown, Broad Street, Wandsworth, West Ham, &c. In 1865 the important outbreak at Newcastle-on-Tyne,‡ when all the circumstances pointed very strongly to the influence of the impure Tyne water. In 1865 occurred the remarkable and undoubted case of water poisoning at Theydon Bois, recorded by Mr Radcliffe,§ and in the following year the violent outbreak in the East of London was supposed to be connected with the circulation of impure water by the East London Water Works Company. Much discussion has taken place as to the real influence of the impure water which it is admitted on all hands was used. Mr Radcliffe|| and Dr Farr¶ have collected the evidence in favour of the opinion that the sudden outburst was really owing to this water; while Dr Letheby and some others have expressed doubts on this point, chiefly on account of the difficulty of reconciling with the hypothesis certain exceptional cases both of immunity and of attack. To me the evidence in favour of the water being the cause appears extremely strong, and far greater difficulty arises if that view is not received than is caused by the exceptional cases referred to, and of which we may not know all the particulars. In the same year (1866) an apparently unequivocal case of production of cholera by the drinking water of a tank on board a steamer occurred at Southampton, and I have recorded the particulars in the Report of the Medical Officer to the Privy Council for 1866.**

During the epidemic in 1866 elsewhere in this country, no such striking instances of local outbreak from water contamination were recorded as in 1849, but there were in some parts, and especially in Scotland, as noticed by Dr Stevenson Macadam,†† very striking coincidences between the abatement of the disease and the introduction of a fresh and pure supply.

In Germany choleraic water poisoning has not only been less noticed, but the great authority of Pettenkofer is against its occurrence. At Munich,

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added the undoubted fact, that there were serious deficiencies of evidence in Dr Snow's early cases. (See review by the author in the "British and Foreign Medical Chirurgical Review," April 1855.)

* Report on the Cholera Outbreak in St James', Westminster, in 1854. London, Churchill, 1855. Every point is discussed in this report with a candour and precision which leaves nothing to be desired. For further evidence on this outbreak, see Indian Sanitary Report: evidence of Dr Dundas Thomson, p. 272.

† On the Mode of Communication of Cholera. By John Snow, M.D. London, Churchill, 2d edition, 1855.

‡ For full particulars, see Dr Farr's Report on Cholera in England, 1866, page 33.

§ Report of the Medical Officer to the Privy Council for 1865 (Eighth Report), p. 438.

|| Report of the Medical Officer to the Privy Council for 1866, p. 266.

¶ Report on the Cholera Epidemic of 1866 in England. Supplement to the 29th Annual Report of the Registrar-General, 1868.

** Report of Medical Officer to Privy Council for 1866, p. 244. In this case the water was foul tasted, and was certainly contaminated with sewage.

†† Transactions of the Royal Scottish Society of Arts, vol. vii. p. 341 (1867).

Pettenkofer* could find no evidence whatever in favour of the spread by water; and Günther, in his careful work on Cholera in Saxony,† asserts that no influence whatever was exerted by drinking water. No evidence could be obtained either in Baden or in villages near Vienna.‡ And as in all cases the observers were not only quite competent, but were fully cognizant of the opinions held in England, this negative evidence is of great weight. At the same time, it can hardly be allowed to outweigh the positive English cases, and, moreover, even in Germany some positive evidence has been lately given. Dr Richter§ attributes a preponderant influence in a local outbreak among the workmen of a sugar-manufactory to the pollution of the drinking water by sewage; and a still more striking case is recorded by Dr Dingcr||, in which the discharges of a cholera patient passed into a brook, in which also the clothes were washed; the water of this brook being used for drinking, there was a sudden and very fatal outbreak affecting the persons who took the water. In Utrecht, also, cholera seemed caused by foul drinking water.¶

In India the evidence for cholera water poisoning is at present rather scanty, though the extremely sudden and severe local outbreaks which often occur there have all the characters of water poisoning. The great cholera outbreak of 1860 and 1861 was attributed by some medical officers to the defilement of the tank water "into which the general ordure of the natives is washed during the rainy season;"** and still more recently, what appears to be a striking instance has occurred. No one can read the able account given by Dr Cunningham and Dr Cutliffe in the Bengal Report for 1867†† of the appearance of cholera among the vast crowd of pilgrims after the great bathing day at Hurdwar, without coming to the conclusion that it was a case of water poisoning on a gigantic scale.

That in India the cholera poison is often carried by water appears probable, not only from the Hurdwar outbreak, but from the very sudden and violent outbreaks and the great sewage contamination in the water of many districts.‡‡

So also in other countries; the attack which caused such losses to the French Division in the Dobrudscha in 1855, when the wells were supposed to be poisoned, and in the English cavalry at Devna,§§ the water was apparently the means of carrying the disease.

In evidence of this kind we must remember that each successive instance adds more and more weight to the instances previously observed, until, from the mere accumulation of cases, the cogency of the argument becomes irresistible.

2. The evidence derived from such local outbreaks is supported by that drawn from the history of more general attacks, in which districts supplied with impure water by a water company have suffered greatly, while other districts in the same locality, and presenting, otherwise, the same conditions, were supplied with pure water and suffered very little. Thus the Registrar-

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* Zeitsch. für Biol. band i. p. 353.

† Die Indische Cholera in Sachsen im Jahre, 1865, p. 125.

‡ Volz and Witlacil, quoted by Hirsch in Jahresb. der gen. Med. for 1867, band ii. p. 221.

§ Archiv der Heilk. 1867, p. 472.

|| Ibid. 1867, p. 84.

¶ Snellen, quoted by Hirsch. Jahresb. der gen. Med. for 1867, p. 222.

** M'William, Epidem. Society Trans. vol. i. p. 274.

†† Report of the Sanitary Commissioner with the Government of India for 1867. Calcutta. 1868. All the particulars of the great outburst of cholera after the religious fair of Hurdwar in 1867 are detailed with a care which leaves nothing to be desired.

‡‡ *Vide* Report on the Sanitary Administration of the Punjaub for 1867, by A. C. C. De Renzy Esq. (Cases of Peshawur and Amritzur.)

§§ I derive this information from a MS. essay of Dr Cattell.

General has shown that the districts supplied in 1853 by the Lambeth Company with a pure water, and part by the Southwark Company with an impure water, suffered much less than the districts supplied by the latter company alone (the proportion was 61 and 94 cases respectively to 100,000 of population); and Dr Snow has shown, by a most elaborate inquiry, that in the districts partly supplied with pure water by the Lambeth Company, and partly with impure water by the Southwark, the attacks of cholera were chiefly in the houses supplied by the latter water.

Thus, in four weeks, in 1853, in this district, there were 334 deaths. Of these, no less than 286 deaths occurred in 40,046 houses supplied with the impure water of the Southwark Company, or 71 to 10,000 houses, and only 14 deaths in 26,107 houses by the Lambeth Company, or 5 to 10,000 houses; in the other cases the water was drawn from other sources.

This is as complete as any inquiry of the kind can be made, for we must assume that all the other conditions of the houses were equal. Granting this, it shows either that the water contained the poison, or predisposed the system to be more easily acted upon by it.

In Berlin, in 1866, in the houses supplied with good water the number of houses in which cholera occurred was 36·6 per cent.; in the houses with bad water was 52·3 per cent.*

3. Additional arguments can be drawn from instances in which towns which could not have had water contaminated with sewage have escaped, and instances in which towns which have suffered severely in one epidemic have escaped a later one, the only difference being that, in the interval, the supply of water was improved. Exeter, Hull, and Newcastle-on-Tyne, Glasgow, Moscow, are instances of this. Two very good cases are related by Dr Acland.† The parish of St Clement was supplied in 1832 with filthy water from a sewer-receiving stream. In 1849 and 1854 the water was from a purer source. In the first year, the cholera mortality was great; in the last years, insignificant. Two gaols were near each other; the one suffered, the other not; the water was impure in one case from drainage, pure in the other. The gaol with bad water having got a fresh supply, the cholera did not appear in the next epidemic.

In looking back, with this new reading of facts, it would seem that some older reported cases of sudden cessation of cholera can be explained, such as the case of Breslau, in 1832, when the shutting up of a pump was followed by the very rapid decline of the disease. Doubtless, however, in other cases the causes of the cessation are different; heavy rain, by cleansing air and sewers, and by stopping the evolution of effluvia, will sometimes as suddenly arrest cholera.

So, also, other curious facts in the history of cholera become explicable. The prevalence of cholera in Russia, with an out-door temperature below zero of Fahr., has always seemed an extraordinary circumstance, and it appeared only possible to explain by supposing that, in the houses, the foul air and the artificial temperature must have given the poison its necessary conditions of development. But Dr Routh has pointed out‡ that, in the poorer Russian houses, everything is thrown out round the dwellings; then owing to the cold, and the expense of bringing drinking water from a distance, the inhabitants content themselves with taking the snow near their houses and melting it. It is thus easy to conceive that, if cholera evacuations are thus thrown

* Die Kanalisation von Berlin, 1868, p. 30.
† Cholera in Oxford in 1854, by H. W. Acland, M.D., p. 51.
‡ Fæcal Fermentation, p. 24.

out, they may be again taken into the body. This is all the more likely, as cholera stools have little smell or taste, and, when mixed even in large quantity with water, are indetectable by the senses.

We may therefore conclude that the cholera evacuations, either at once or after undergoing, as supposed by Pettenkofer and Thiersk, some fermentative change, pass into drinking water or float about in the atmosphere. In either case they are received into the mouth and swallowed, and produce their effects directly on the mucous membrane, or are absorbed into the blood. The relative frequency of each occurrence, the incubative period, and the severity of the disease produced, are points still uncertain.

In addition to the production of cholera from drinking water containing the cholera stools, it has been supposed that the use of impure water of any kind *predisposes* to cholera, though it cannot absolutely produce the disease. The facts already quoted on the influence of the Lambeth water seem to support this view; but some German evidence in 1866 does not favour it.* If the water acts in this way, it can only be by causing a constant tendency to diarrhœa, or by carrying into the alimentary canal organic matter which may be thrown into special chemical changes by a small quantity of cholera poison, which has been introduced with air or food and swallowed.

Yellow Fever.

As, like dysentery, typhoid fever, and cholera, the alimentary mucous membrane is primarily affected in yellow fever, there is an *a priori* probability that the cause is swallowed also in this case, and that it may possibly enter with the drinking water. But no good evidence has been yet brought forward.

Boudin† quotes a case from Rochard in which a French frigate (in 1778) took in water at San Jago, where yellow fever prevailed. Some days afterwards yellow fever broke out with such violence, that two-thirds of the crew were attacked. "And the proof that the only cause was the water," says Rochard, "was that the persons living with the captain had with them jars filled with water from Europe, and all escaped." Boudin very properly observes, that this evidence is very defective; but yet we must remember how completely the propagation of marsh and typhoid fevers, and of cholera by water, has been overlooked, and how exactly this sudden and extensive attack resembles the case of the Argo.

The Barrack Commissioners have also directed attention to the fact of the great impurity of the water at Gibraltar at the time of the yellow fever epidemic.

The other Zymotic Diseases.

No decided evidence has yet been given that any other of the specific diseases are propagated in this way, but Dr Macadam has brought some evidence to show that erysipelas and throat ulcer may have a water origin.‡

4. DISEASES OF THE SKIN, AND SUBCUTANEOUS TISSUES.

A curious endemic of boils occurred in the vicinity of Frankfort in 1848. It was confined to a small number of persons, and presented favourable

* See Report on Hygiene, Army Medical Reports, vol. vii. p. 352.
† Traité de Geog. et de Stat. Méd. 1858. t. i. p. 141.
‡ Trans. of the Royal Scottish Society of Arts, 1867.

opportunities for investigation. An elaborate inquiry was made by Dr Clemens,* which certainly seems to indicate that the complaint was caused by drinking water containing sulphuretted hydrogen gas, which was set free in some large chemical works, and was washed down by the rains into the brooks from which drinking water was derived. The case is most elaborately and logically argued, but it certainly seems remarkable that other instances of the same kind should not have been observed, especially as in some trades there is disengagement of large quantities of SH_2 into the atmosphere, and as the drinking of sulphuretted springs is so common.

The peculiar forms of boil or ulcer common in many cities in the East have been in some cases referred to the water. The Aleppo evil, the Damascus ulcer, and some other diseases of an analogous kind, which have the peculiarity of occurring only once in life, are possibly more connected with the true contagions; but the unhealthy boils or ulcers so common in India, especially in the north-west and along the frontier, are probably connected with bad water. The so-called Delhi boil has, for example, much decreased in frequency since the waters of the Jumna were used instead of the impure well water.†

The elephantiasis of the Arabs (the so-called Barbadoes leg or pachydermia) has been ascribed to organic impurities in water, but on no very stringent evidence.

5. DISEASES OF THE BONES.

Water impregnated with sulphurous acid gives rise in cattle to a number of serious symptoms, among others to diseases of the bones. The sulphurous acid evolved from the copper works at Swansea has caused numerous actions on account of the loss of herbage and cattle. Rossignol‡ states that water highly charged with calcium carbonate and sulphate was found to give rise to exostoses in horses; pure water being given, the bones ceased to be diseased. Hard water is said to make horses' coats rough.

6. CALCULI.

It has long been a popular opinion that drinking lime waters give rise to calculi (calcium phosphatic and oxalate). Several medical writers have held the same opinion, and have adduced individual instances of calculi (phosphatic?) being apparently caused by hard waters, and cured by the use of soft or distilled water. On a large scale, statistical evidence is, as far as I know, wanting. The excess of cases of calculi in Norwich and Norfolk generally is not, in Dr Richardson's opinion, attributable to the water.§

Professor Gamgee, however, states that sheep are particularly affected by calculus in the limestone districts.

7. GOITRE.

The opinion that impure drinking water is the cause of goitre is as old as Hippocrates and Aristotle, and has been held by the majority of physicians.

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* Henle's Zeitschrift für Nat. Med. 1849, vol. viii. p. 215.

† See Annual Report of San. Com. with the Government of India for 1867, p. 178 (1868). Some excellent analyses of the Delhi waters are given by Dr Sheppard; *vide* Dr Macnamara's Second and Third Reports of the analyses of potable waters in the Bengal Presidency. Calcutta, 1868.

‡ Traité d'Hygiène Militaire, 1857, p. 357.

§ Med. History of England; Medical Times and Gazette, 1864, p. 100.

The opinion may be said actually to have been put to the test of experiment, since both in France and Italy the drinking of certain waters has been resorted to, and apparently with success, for the purpose of producing goitre, and thereby gaining exemption from military conscription.* And this is supported by the evidence of Bally, Coindet, and by many of the French army surgeons, who have seen goitre produced even in a few days (8 or 10) by the use of certain waters.† While, conversely, Johnston saw goitre, which was common in a goal, disappear when a pure water was used.‡ Apart from this, the evidence for the causation by water is extremely strong, many cases being recorded where, in the same village, and under the same conditions of locality and social life, those who drank a particular water suffered, while those who did not do so escaped.§ The latest author who has written on this subject, and who has accumulated an immense amount of evidence, M. Saint-Lager, expresses himself very confidently on the point.

The impurity in the water which causes goitre is not yet precisely known. It is certainly not owing to the want of iodine, as stated by Chatin, and there is little probability of its being caused by organic matters, by fluorine, or by silica. On the other hand, the coincidence of goitre with sedimentous water is very frequent. Since the elaborate geological inquiries of M. Grange‖ and the analyses of the waters of the Isère, magnesian salts in some form have been often considered to be the cause, to which many add lime salts also; and certainly the evidence that the waters of goitrous places is derived from limestone and dolomitic rocks, or from serpentine in the granitic and metamorphic regions, is very strong. The investigations now include the Alps, Pyrenees, Darphiné, some parts of Russia, Brazil, and districts in Oude in North-West India. A table compiled from Dr M'Clellan's work¶ is very striking:—

Goitre and Cretinism in Kumaon (Oude).

Water derived from	Percentage of Population affected.	
	With Goitre.	With Cretinism.
Granite and gneiss,	0·2	0
Mica, slate, and hornblende,	0	0
Clay slate,	0·54	0
Green sandstone,	0	0
Limestone rocks,	33	3·1

There are, however, not wanting analyses of water of goitrous regions which show that magnesia may be absent (in Rheims, according to Maumené; in Auvergne, according to Bertrand; in Lombardy, according to Demortain;

* Among other evidence on this point, the late work of M. Saint-Lager (Sur les causes du Cretinism et du Goitre endémique, Paris, 1867) may be cited (p. 191, *et seq.*), as he appears to have carefully looked into the evidence. See also Baillarger (Comptes Rendus de l'Acad. t. lv. p. 475), who also states, though this has been denied by Rey, that horses and mules become affected from drinking the water of the Isère.

† Encyclopædia of Practical Medicine, vol. i. art. Bronchocele, p. 326.

‡ Edin. Monthly Journal, May 1855.

§ Saint-Lager (*op. cit.*) cites several strong cases (p. 192, *et seq.*)

‖ Ann. de Chimie et de Phys. vol. xxiv. p. 364.

¶ Medical Topography of Bengal. I have included the facts on cretinism also, without desiring to express any opinion on the relation between goitre and cretinism.

while Saint-Lager enumerates other cases), while it has been also denied that there need be any excess of lime. M. Saint-Lager, basing his opinion partly on these negative instances, partly from his own experiments with the soap-test, which show no relation between hardness of water and goitre, and partly from the negative results of experiments on animals with calcium sulphate and magnesian salts, denies altogether the connection between goitre and calcium and magnesium sulphates and carbonates. He states also that M. Grange has now himself given up the belief of magnesia being the essential agent of goitre,* and argues that the constituent of the water which is the actual cause is either iron pyrites (ferrum sulphide), or more infrequently copper or some other metallic sulphide. And he explains M'Clellan's results by the supposition, based on an expression of that writer, that in the limestone districts of Kumaon the water had traversed the metalliferous strata of the rocks. Saint-Lager does not, as far as I see, support his opinion by actual chemical analyses, but he brings forward geological evidence on a large scale, to prove that the endemic appearance of goitre coincides with the metalliferous districts. He has also made experiments on animals with iron salts, which do not appear conclusive, though he believes he produced in some cases an effect on the thyroid. His hypothesis seems to me to fail from this want of chemical analysis. He has made out a case for inquiry rather than for conclusion, or, as he says himself, the iron sulphide is more in the position of an accused person than of one whose guilt has been proved.

It seems clear that while it may be admitted that impure water is the cause of goitre, there ought to be renewed chemical analyses, and it would not seem difficult to decide such a point by a properly conducted inquiry.

The amount of lime and magnesian salts required to produce goitre is not precisely known. In the gaol at Durham, Johnston† states that when the water contained 77 grains per gallon (chiefly of lime and magnesian salts), all the prisoners had swellings of the neck; these disappeared when a purer water, containing 18 grains in the gallon, was obtained.

Goitre may be rapidly produced. Bally noticed that certain waters in Switzerland would cause it, even in eight or ten days, and cases almost as rapid have occurred in other places.‡

8. ENTOZOA, OR OTHER ANIMALS.

Whereas the *Tænia solium* and the *Tænia mediocanellata*, and many entozoa, find their way into the body with the food, the two forms of the *Bothriocephalus latus* (*T. lata*) seem to find their way into the body principally or entirely in the drinking water.§ Both embryo and eggs (but principally, or perhaps entirely, the former) exist in the river water. The ciliated embryo moves for several days very actively in water; it may then, after a time, lose its ciliary covering, and then, not being able to move further, perishes; or it may find its way into the bodies of man and animals, and there develop into the *Bothriocephalus latus*.

It is most common in the interior of Russia, Sweden, in part of Poland, and in Switzerland.

* Sur les causes der Cretin. et der Goitre, p. 237.

† Edin. Monthly Journal, May 1855.

‡ Many instances are recorded in the French Military Medical Journal, Recueil de Mém. de Méd. Mil., of the acute goitre, produced in a few days.

§ See especially a paper by Dr Knock in the Peterburger Med. Zeitsch. for 1861. An abstract is given in the Lancet, Jan. 25, 1862; and the paper in full is printed in Virchow's Archiv, band xxiv. 453.

The *Ascaris lumbricoides* (Round-worm) appears also sometimes to enter the body by the drinking water. At Moulmein, in Burmah, during the wet season, and especially at the commencement, both natives and Europeans, both sexes and all ages, were, during my service twenty-six years ago, so affected by lumbrici, that it was almost an epidemic.* The only circumstance common to all classes was that the drinking water, drawn chiefly from shallow wells, was greatly contaminated by the substances washed in by the floods of the excessive monsoon which prevails there. Dr Paterson has also noticed similar facts in England (Aitken's "Practice of Medicine," 5th edition, i. p. 914).

Leuckardt† has no doubt of the passage of the ascarides' eggs into drinking water; and, indeed, they have been actually seen in drinking water by Mosler.‡ But it seems yet doubtful (as all experiments have failed in producing from the drinking water the worms in animals) whether the eggs alone will suffice, and it seems possible that they must pass through some other host before developing in the human intestine. Mosler attributed in his case much influence to the large amount of vegetable food taken by the persons affected. The *Dochmius duodenalis* (*Strongylus duodenalis*, *Anchylostomum duodenale*) would appear from Leuckardt's statement§ to be introduced by impure water.‖

Filaria Dracunculus (Guinea-worm).—The introduction by water of the Filaria has long been a favourite opinion. It has been a matter of debate whether it is taken into the stomach as drink, and thence finds its way (like the Trichina, to the muscles) into the subcutaneous cellular tissue, or whether it penetrates the skin during bathing or wading in streams. The latter opinion seems to be the most probable in the majority of cases.¶

Boiling the water before drinking appears to have some preservative effect.**

Leeches.—Reference has already been made to the swallowing of small leeches, which fix on the pharynx and in the posterior nares. In a march of the French near Oran, in Algiers, more than 400 men were at one time in hospital from this cause. In some cases the repeated bleedings from the larynx have simulated hæmoptysis and phthisis, and have produced anæmia. A leech, once fixed, seldom falls off spontaneously. In India, no accidents of this kind are on record, yet we must assume that they occasionally occur.

9. LEAD, MERCURY, ARSENIC, COPPER, AND ZINC POISONING.

It is only necessary to mention the fact of metals passing into the drinking water, either by trade refuse being poured into streams, or by the water dissolving the metal as it flows through pipes or over metallic surfaces. (See page 15.)

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* The native treatment is the powder of a fungus (Wah-mo), derived from the female bamboo. It is most useful. See paper by the author in the London Journal of Medicine, 1849.

† Die Menschlich. Parasiten, band ii. p. 220.

‡ Virchow's Archiv, band xviii. p. 249.

§ Ibid. band ii. p. 455.

‖ The importance of the discovery of Griesinger (Archiv für Phys. Heilk, 1854, p. 555), that the so-called Egyptian chlorosis, which affects in some places nearly the half of the population, is caused by the *Dochmius duodenalis*, has hardly been sufficiently appreciated. Not only anæmia and liver diseases, but symptoms referred to dysentery and hæmorrhoides, are often also produced. And as similar facts have now been observed in Brazil, it seems impossible but that in India the formidable affections caused by the Dochmius should not be common. The discovery of Griesinger is only second in importance, if it be so, to the discovery of Trichinosis, or the recognition of the Echinococcus disease of Iceland, which affects half the population.

¶ See Dr Aitken's long and excellent chapter on this disease, in the first volume of his Practice of Medicine, 5th edition, p. 927, *et seq.*, for a discussion on the water and earth question.

** Greenhow in Indian Annals, 1856, p. 557.

General Conclusions.

1. An endemic of diarrhœa, *in a community*, is almost always owing either to impure air, impure water, or bad food. If it affects a number of persons suddenly, it is probably owing to one of the two last causes, and, if it extends over many families, almost certainly to water. But as the cause of impurity may be transient, it is not always easy to find experimental proof.

2. Diarrhœa or dysentery, constantly affecting a community, or returning periodically at certain times of the year, is far more likely to be produced by bad water than by any other cause.

3. A very sudden and localised outbreak, of either typhoid fever or cholera, is almost certainly owing to introduction of the poison by water.

4. The same fact holds good in cases of malarious fever, and especially if the cases are very grave, a possible introduction by water should be carefully inquired into.

5. The introduction of the ova of certain entozoa by means of water is proved in some cases—is probable in others.

6. Although it is not at present possible to assign to every impurity in water its exact share in the production of disease, or to prove the precise influence on the public health of water which is not extremely impure, it appears certain that the health of a community always improves when an abundant and pure water is given; and, apart from this actual evidence, we are entitled to conclude, from other considerations, that abundant and good water is a primary sanitary necessity.

CHAPTER II.

AIR.

That the breathing of air, rendered impure from any cause, is hurtful, and that the highest degree of health is only possible when to the other conditions is added that of a proper supply of pure air, might be inferred from the physiological evidence of the paramount importance of proper aeration of the blood. Experience strengthens this inference. Statistical inquiries on mortality prove beyond a doubt that of the causes of death, which usually are in action, impurity of the air is the most important. Individual observations confirm this. No one who has paid any attention to the condition of health, and the recovery from disease of those persons who fall under his observation, can doubt that impurity of the air marvellously affects the first, and influences and sometimes even regulates the second.* The average mortality in this country increases tolerably regularly with density of population. Density of population usually implies poverty and insufficient food, and unhealthy work, but its main concomitant condition is impurity of air from overcrowding,† deficiency of cleanliness, and imperfect removal of excreta, and when this condition is removed, a very dense and poor population may be perfectly healthy. The same evidence of the effect of pure and impure air on health and mortality is still more strikingly shown by horses; for in that case the question is more simple on account of the absolute similarity in different periods or places of food, water, exercise, and treatment. Formerly, in the French army, the mortality among the horses was enormous. Rossignol‡ states that, previous to 1836, the mortality of the French cavalry

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* See the chapter on Hospitals for detailed proof.

† See Dr Duncan's evidence in the Health of Towns' Reports, vol. i. p. 131. On this point Dr Gairdner has also brought together some good evidence in his work on "Public Health in relation to Air and Water," p. 52, *et seq.*

The following part of his table may be quoted :—

Population to one square mile in districts taken in England.	Deaths per 1000 per annum.	Population to one square mile in districts taken in England.	Deaths per 1000 per annum.
56	15	324	22
106	16	485	23
144	17	1216	24
149	18	1262	25
182	19	2064	26
202	20	2900	27 and upwards.
220	21		

Admitting that several causes are acting here, the increase is so regular as to lead to the belief that one grand condition must be dominant.

‡ Traité d'Hygiène Militaire. Paris, 1857.

horses varied from 180 to 197 per 1000 per annum. The enlargement of the stables, and the "increased quantity of the ration of air," reduced the loss in the next ten years to 68 per 1000. At present it is said to be a little greater than this, viz., 85 per 1000, of which about 50 per 1000 is from glanders or farcy.* But in some cases in the French army a much greater ventilation has reduced the mortality still more. In the Italian war of 1859, M. Moulin, the chief veterinary surgeon, kept 10,000 horses many months in barracks open to the external air in place of closed stables. Scarcely any horses were sick, and only one case of glanders occurred.†

In the English cavalry (and in English racing stables) the same facts are well known. Wilkinson‡ informs us that the annual mortality of cavalry horses (which was formerly great) is now reduced to 20 per 1000, of which one-half is from accidents and incurable diseases. Glanders and farcy have almost disappeared, and if a case occurs, it is considered evidence of neglect.

The food, exercise, and general treatment being the same, this result has been obtained by cleanliness, dryness, and the freest ventilation. The ventilation is threefold—ground ventilation, for drying the floors; ceiling ventilation, for discharge of foul air; and supply of air beneath the horses' noses, to dilute at once the products of respiration.

In cow-houses and kennels similar facts are well known; disease and health are in the direct proportion of foul and pure air.

The air may affect health by variations in the amount or condition of its normal constituents, by differences in physical properties, or by the presence of impurities. While the immense effect of impure air cannot be for a moment doubted, it is not always easy to assign to each impurity its definite action. The inquiry is, in fact, in its infancy; it is difficult, and demands a more searching analysis than has been, or perhaps than can be at present, given. When impure air does not produce any very striking disease, its injurious effects may be overlooked. And in this, it appears to me, consists the fallacy of some of Parent-Duchâtelet's observations. In many cases he looked in vain for fever or for marked diseases. But we now know that unless the specific cause be present, no mere foulness of air will produce a specific disease. The evidences of injury to health from impure air are found in a larger proportion of ill health—*i.e.*, of days lost from sickness in the year—than under other circumstances; an increase in the severity of many diseases, which, though not caused, are influenced by impure air; and a higher rate of mortality, especially among children, whose delicate frames always give us the best test of the effect both of food and air. In many cases accurate statistical inquiries on a large scale can alone prove what may be in reality a serious depreciation of public health.

The quantity of air necessary for perfect health will be considered in the chapter on Ventilation. I shall in the present chapter enumerate the impurities, and then the diseases attributable to them.

It would be occupying unnecessary space to enlarge on the composition of pure air. In addition to oxygen and nitrogen, there are the following substances:—carbonic acid, watery vapour, organic matter. Perhaps, also, the almost universally diffused salts of soda should be reckoned as normal constituents. Alterations in, or specific states of these gases (ozone), are considered in the chapter on Climate.

The amount of watery vapour varies in different countries greatly, from about

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* Wilkinson—Journal of the Royal Agricultural Society, No. 50, p. 91, *et seq.*
† Larrey—Hygiène des Hôp. Mil. 1862, p. 63.
‡ *Op. cit.*

40 per cent. of saturation to perfect saturation; or, according to temperature, from 1 to 11, or even 12 grains in a cubic foot of air, if that expression may be admitted. The best amount for health has not been determined, but it has been supposed it should be from 65 to 75 per cent.; but in many healthy climates it is much more than this. (See CLIMATE.)

The amount of carbonic acid in normal air ranges from ·02 to ·05 per cent. (or from 2 to 5 volumes in 10,000); it increases slightly up to 11,000 feet of elevation, then decreases; it is slightly augmented under certain circumstances; as in sea air by day, though not at night; the difference being between ·054 to ·033 per cent. (Lewy).

The normal amount of organic matter is not known, if indeed it is not to be considered as an impurity.

SECTION I.

IMPURITIES IN AIR.

A vast number of substances, vapours, gases, or solid particles, continually pass into the atmosphere. Many of these substances can be detected neither by smell nor taste, and are inhaled without any knowledge on the part of those who breathe them. Others are smelt or tasted at first; but in a short time, if the substance remains in the atmosphere, the nerves lose their delicacy; so that, in many cases, no warning, and in other instances, slight warning only, is given by the senses of these atmospheric impurities.

As if to compensate for this, a wonderful series of processes goes on in the atmosphere, or on the earth, which keeps the air in a state of purity.

Gases diffuse, and are carried away by winds, and thus become so diluted as to be innocuous; or are decomposed if compound, or are washed down by rain: solid substances lifted into the air by winds, or by the ascensional force of evaporation, fall by their own weight; or if organic, are oxidised into simple compounds, such as water, carbonic acid, nitric acid, and ammonia; or dry and break up into impalpable particles, which are washed down by rain. Diffusion, dilution by winds, oxidation, and the fall of rain, are the great purifiers; and in addition, there is the wonderful laboratory of the vegetable world, which keeps the carbonic acid of the atmosphere within certain limits.

If it were not for these counterbalancing agencies, the atmosphere would soon become too impure for the human race. As it is, it is wonderful how the immense impurity, which daily passes into the air, is soon removed, except when the perverse ingenuity of man opposes some obstacle, or makes too great a demand even upon the purifying powers of Nature.

The air passing into the lungs in the necessary and automatic process of respiration, is drawn successively through the mouth and nose, the fauces, and the air-tubes. It may consist, according to circumstances, of matters perfectly gaseous (as in pure air), or of a mixture of gases and solid particles, mineral or organic, which have passed into the atmosphere.

The truly gaseous substances will doubtless enter the passages of the lungs, and will meet there with that wonderful surface, covered with the most delicate tufts of blood-vessels, unshielded even, it is supposed by some, by epithelium, which stand up on the surface of 5,000,000 or 6,000,000 air-cells, and through which the blood flows with great velocity; there they will be absorbed, and if, as has been calculated, the surface of the air-cells is as much as from 10 to 20 square feet (and some have placed these figures much higher), we can well understand the ease and rapidity with which gaseous substances will enter the blood.

The solid particles or molecules entering with the air, may lodge in the mouth or nose, or may pass into the lungs,* and there decompose, if of destructible nature; or may dissolve or break down if of mineral formation; or may remain as sources of irritation until dislodged; or perhaps become covered over with epithelium, like the particles of carbon in the miner's lung.

If such particles lodge in the mouth or nose they may be swallowed, and pass into the alimentary canal, and it is even more probable that this should be the case with all except the lightest and most finely divided substances, than that they should pass into the lungs. Although incapable of present proof, there is some reason to think that some of the specific poisons, which float about in an impure atmosphere, such as those which arise from the typhoid or cholera evacuations, may produce their first effects, not on the lungs or blood, but on the alimentary mucous membrane, with which they are brought into contact when swallowed.

SUB-SECTION I.—SUSPENDED MATTERS.

Nature of Suspended Substances.—An immense number of substances, organic and inorganic, may be suspended in the atmosphere. From soil the winds lift silica, finely powdered silicate of alumina, carbonate of lime, phosphate of lime, and peroxide of iron. Volcanoes throw fine particles of carbon, sand, and dried mud, which passing into the higher regions, may be carried over hundreds of miles.

The animal kingdom is represented by the debris of the perished creatures who have lived in the atmosphere, and also it would appear that the ascensional force of evaporation will lift even animals of some magnitude from the surface of marsh water. The germs, also, of Vibrio, Bacteria, and Monads (if we may call these animals) are largely present, and small eggs of various kinds.

From the vegetable world pass up seeds and debris of vegetation; pollen, spores of fungi, mycoderms, mucedines, which may grow in the atmosphere, and innumerable volatile substances or odours. The number of spores of fungi is incredible. In water through which the air of Manchester was drawn by Dr Angus Smith, 250,000 fungoid spores, as well as mycelium, were found in a single drop by Mr Dancer. When kept, monads and rotiferæ made their appearance.

From the sea the wind lifts spray, and the chloride of sodium becoming dried, is so diffused through the atmosphere, that it is difficult, on spectrum analysis, to find a spectrum without the yellow line of soda.

The works and habitations of man, however, furnish matters probably of much greater importance in a hygienic point of view.

Particles of carbon from imperfect combustion of wood or coal, or from breaking up of masses of coal, are, of course, extremely common; starch-cells, among all bread-eating nations, appear scarcely less so. Bits of vegetable tissue, some weatherworn, some half-burnt (in the air of towns) are common. In manufacturing districts, or in certain trades, there may be cotton fibres, hair, particles of wool, particles of iron, steel, stone, clay, &c., &c., and the diffusion of these particles plays a very prominent part in the production of lung diseases (bronchitis, emphysema, phthisis), and of stomach diseases (dyspepsia). In other trades, as in that of the painter, the volatilising turpentine may, it is believed, carry into the air particles of plumbic carbonate,

* The evidence of "miners' phthisis" proves this; but in addition, Professor Zenker has published cases in which snuff and different coloured powders have been found in the lungs of workmen employed in workshops in which such particles have been mixed with air.

while little clouds of arsenious acid may come from paper or clothes which are coloured with arsenic.

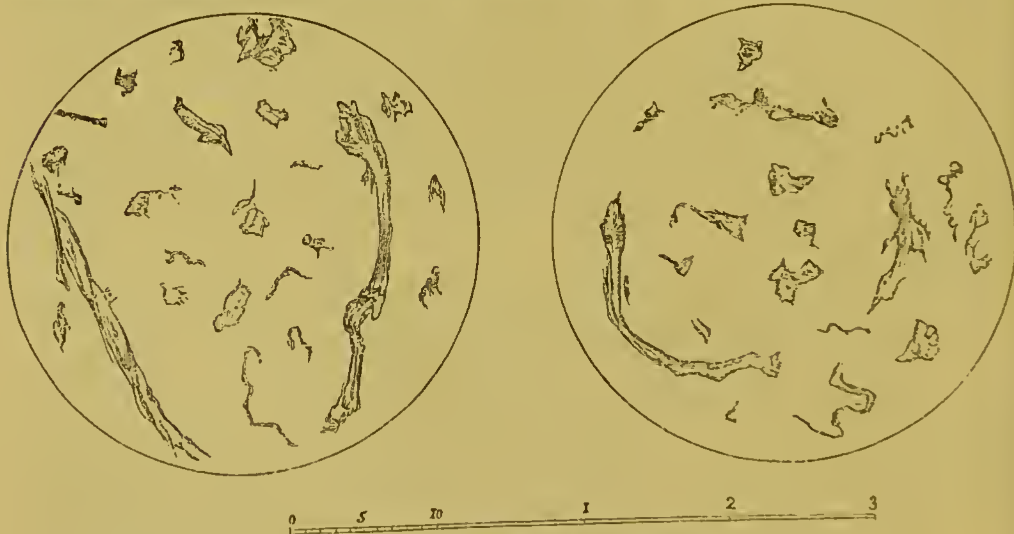
In addition to this, dried organic substances are, like fine particles of soil, lifted from the ground by wind, and are possibly carried for some distance. In some such way, in all probability, certain diseases are propagated, the dried substance, as for example, the evacuations of cholera or dysentery, floating through the air, and being finally swallowed or inhaled into the lungs.

The specific poison of smallpox derived from the skin; of scarlet fever derived from the skin, throat, urine (?); of measles derived from the skin and lungs (?), &c., must also be molecular organic matter, or even formed corpuscles, though as yet they have not been recognised.

But not only are such impalpable fine dry powders lifted into and carried in the air, but organised particles, still retaining their form, may be lifted by the force of evaporation of water. Eiselt discovered pus cells in the air of an ophthalmic ward; and epithelium cells are found in all ill-ventilated rooms.*

The extent to which pus or epithelium cells contribute in forming the organic matter which accumulates in badly cleaned hospitals, is shown by the experiments of Chalvet in the wards of St Louis.† The dust collected, when the wards were being cleaned, was found in one experiment to contain 36 per cent. of organic matter, and in another experiment 46 per cent. This organic matter consisted in great measure of epithelium cells; when burnt it gave out an odour of horn, when moistened and allowed to decompose it gave out a fœtid putrid smell.

I have examined the air of various barracks and military hospitals, and have detected large quantities of epithelium from the skin, and perhaps the mouth; particles of cotton, wool, and other matters of uncertain origin. Drs Frank, Hewlett, St John Stanley, Baynes Reed, M'Cully, and others, of the



Scale of 100ths of an inch.

Fig. 9.—Suspended matter in the air of the Barracks at Gravesend.

Army Medical Service, have also made many experiments on this subject, and several notices on the point will be found in the very careful papers of Dr de Chaumont in the Army Medical Department Reports.‡

* First detected by Dundas Thomson in the air of a cholera ward in 1849 and in 1854.

† Ann. d'Hygiène. July 1862, p. 240.

‡ Army Medical Reports for 1860–1868. Several papers on Ventilation of Barracks, Hospitals, and Stables, will be found. The figure given above is a copy of the woodcut given in the excellent paper on the ventilation of the barracks at Gravesend, by Messrs Hewlett, Stanley, & Reed.

In all tainted atmospheres of this kind, it would appear that the germs of infusoria abound to a much greater extent than in pure air. M. Lemaire* found in the air of a prison numerous round or oval bodies, and precisely the same forms in the sweat of dirty persons. It seems probable that the discovery of suspended matters of this kind will lead to most important results. The possibility of a direct transference from body to body of cells undergoing special chemical changes is thus placed beyond doubt, and the doctrine of contagion receives an additional elucidation. It remains to be seen whether pus and epithelium cells becoming dried in the atmosphere can again, on exposure to warmth and moisture, undergo the chemical changes which had been interrupted, or whether they would not rather break down into impalpable particles, and be then totally oxidised and destroyed. It is now generally admitted that protophytes, like the *Protococcus pluvialis*, may be dried and yet retain their vitality even for years, and may be blown about in atmospheric currents; but it would not be right to infer a similar power on the part of epithelium or pus cells.

SUB-SECTION II.—GASEOUS SUBSTANCES.

A great number of gases may pass into the atmosphere either from natural causes or from the works of man.

Compounds of Carbon.—Carbonic acid (abnormal if exceeding 5 in 10,000 parts), carbonic oxide, carburetted hydrogen, and peculiar substances (gaseous) in sewage air.

Compounds of Sulphur.—Sulphurous acid, sulphuric acid, sulphuretted hydrogen, ammonium sulphide, and carbon bisulphide.

Compounds of Chlorine.—Hydrochloric acid.

Compounds of Nitrogen.—Ammonia and ammonium acetate, sulphide, and carbonate (normal in small amount?), and nitrous and nitric acids.

Compounds of Phosphorus.—Phosphoretted hydrogen.

Organic Vapours.—Of the exact composition of the vapours, often fœtid, which arise from various decomposing animal matters, little is known. The vapours of sewage have been examined by Odling, and were found to be carbo-ammoniacal, containing more carbon than methylamine, and less than ethylamine.

SUB-SECTION III.—NATURE OF IMPURITIES IN CERTAIN SPECIAL CASES.

Air Vitiated by Respiration.

An adult man, in ordinary work, gives off in twenty-four hours from 12 to 16 cubic feet of carbonic acid gas, and also emits an undetermined quantity of carbonic acid gas by the skin. On an average, an adult man, not doing excessive work, may be considered to give to the atmosphere every hour ·6 cubic feet of carbonic acid. Women give off less, and children and old people also give off a smaller amount.

The amount of carbonic acid in pure air being assumed to be on an average 0·4 per 1000, or 4 volumes per 10,000, the quantity in the air of rooms vitiated by respiration is as follows:—

	Per 1000 volumes.
Barrack (unventilated) in London (Roscoe), .	1·242
" " " ("), .	1·189
" " Chatham (Fyffe), .	1·95

* Comptes Rendus de l'Acad. Oct. 1867, p. 637.

	Per 1000 volumes.
Military hospital at (Fort Pitt) Chatham—numerous observations,	1·800 to 0·600
Barracks at Aldershot (de Chaumont) (different plans of ventilation),	1·408 to 0·642
Barrack at Hilsea, over stable (de Chaumont),	1·214 to 1·078
Barrack-hut at Hilsea, not over stable (de Chaumont),	·593
Orderlies' barracks at Netley (Notter and Mackenzie),	1·98 to 0·98
Hospital at Netley (numerous observations),	·800 to ·600
Herbert Hospital, Woolwich (de Chaumont),	·601
General Hospital, Madrid,	3·2 to 4·3
Boys' school (Roscoe)—22,141 cubic feet, and 164 boys for $2\frac{1}{2}$ hours, with bad ventilation,	2·371
Boys' school (Roscoe)—4640 cubic feet and 67 boys,	3·100
Air of a crowded meeting (Roscoe),	3·65
Sleeping-room in Salpêtrière,	4·000
" "	5·000
" Madrid (Da Luna),	4·8
Schoolroom—10,400 cubic feet and 70 girls, (Pettenkofer),	7·230
Horse stable in Ecole Militaire, with badly-closing doors,	7·000
Stable at Hilsea (de Chaumont), cubic space 655 feet per horse,	1·053
Stable at Hilsea (de Chaumont), cubic space 1000 feet per horse,	·593

The carbonic acid of respiration is equally diffused through the air of the room (Lassigne, Pettenkofer, Roscoe); it is very rapidly got rid of by opening windows (Gore), and in this respect differs from the organic matter, and probably from the watery vapour; neither appear to diffuse rapidly or equably through a room.

By the skin and lungs pass off from 25 to 40 ounces of water in 24 hours, to maintain which, in a state of vapour, 211 cubic feet of air per hour is necessary on an average. Of course, however, temperature and the hygrometric condition of the air greatly modify this.

Organic matter is also given off, the amount of which has never been precisely determined, and has been variously estimated at from 10 to 240 grains.* Nor is it possible, at present, to estimate it correctly. This organic matter must be partly suspended, and is made up of small particles of epithelium and fatty matters detached from the skin, and partly of an organic vapour given off from the lungs and mouth. The organic matter from the lungs, when drawn through sulphuric acid, darkens it; through permanganate of potash, decolorises it; and through pure water, renders it offensive. Collected from the air by condensing the watery vapour on the sides of a globe containing ice (as by Taddei in the wards of the Santa Maria Novella), it is found to be precipitated by nitrate of silver, to decolorise potassium permanganate, to blacken on platinum, and to yield ammonia. It is therefore nitrogenous and oxidisable. It has a very fœtid smell, and this is retained in a room for so long a time, sometimes for four hours, even when there is free ventilation, as to show it is oxidised slowly. It is probably in combination with water, for the most hygroscopic substances absorb most of

* Report on Hygiene in the Transactions of the American Medical Association, 1850.

it. It is absorbed most by wool, feathers, damp walls, and moist paper, and least by straw and horse-hair. The colour of the substance influences its absorption in the following order :—black most, then blue, yellow, and white. It is probably not a gas, but is molecular, and floats in clouds through the air, as the odour is evidently not always equally diffused through a room. In a room, the air of which is at first perfectly pure, but is vitiated by respiration, the smell of organic matter is generally perceptible when the CO_2 reaches ·7 per 1000 volumes, and is very strong when the CO_2 amounts to 1 per 1000. From experiments made at Gravesend, Netley, and Hilsea, by various medical officers,* it has been shown that the amount of potassium permanganate destroyed by air drawn through its solution is generally in proportion to the amount of carbonic acid of respiration.

It is indeed asserted by Gaultier de Claubry (Ann. d'Hygiène, April 1861, p. 348), that in barracks, some minutes only after the soldiers had entered, the smell of organic matter was perceptible, though there was at that time no augmentation in carbonic acid.

Assuming that the organic matter (of different sources) has an effect on potassium permanganate equal to that which sugar has,† Dr Angus Smith has calculated the amount of organic matter to be—

	Cubic feet of air.
In a bedroom, ...	1 grain in 64,000
,, ...	,, 56,000
Inside a house, ...	,, 16,000
In a closely-packed railway-carriage, .	,, 8,000
When the air of a sewer entered a house,	,, 8,000
Ash of midden or cesspool, . .	,, 62
Pure air on high ground, . .	,, 176,000
,, ,, . .	,, 209,000

Air of Sick-Rooms.

In addition to being vitiated by respiration, the air of sick-rooms is contaminated by the abundant exhalations from the bodies, and by the effluvia from discharged excretions. The quantity of organic matter is known to be large, but it is difficult at present to give a quantitative statement. Moscati, who (in 1818) condensed the watery vapour of a ward at Milan, describes it as being slimy, and as having a marshy smell. The peculiar smell of an hospital is indeed very remarkable, and its similarity in hospitals of different kinds seems to show that the odorous substance has a similar composition in many cases. The reaction of ozone appears not to be given in such an atmosphere.

Devergie found an "immense amount" of organic matter in the air in the vicinity of a patient with hospital gangrene.

The composition of the dust of a ward in St Louis, in Paris, examined by Chalvet, has been already noticed (p. 88). The dust collected in hospitals for diseases of the skin is stated by Gailleton to be full of sporules of the Trichophyton.

Much interest was excited in 1849 by the discovery by Drs Brittan and Swayne of Clifton of bodies very like fungi in the air of a cholera ward; later researches lead to the opinion that this observation was perfectly cor-

* By Drs Hewlett (Bombay Army), St John Stanley, Baynes Reed (12th Regiment), Innes (16th Lancers), Venning (1st Life Guards), Martin (Staff), and especially de Chaumont (Staff-Surgeon).

† In using these numbers, it must be remembered that they involve an assumption of the equality of action of sugar and organic matter. It is perhaps safer to express the relation directly between the permanganate and organic matter by stating the amount of air necessary to decolorise a definite amount of permanganate.

rect, though the connection between these fungi and cholera is still quite uncertain. In 1849, also, Dr Dundas Thomson drew the air of a cholera ward through sulphuric acid; various suspended substances were arrested: starch, woollen fibres, epithelium, fungi or spores of fungi and vibriones. Mr Rainy also found in the air of a cholera ward in St Thomas' Hospital the spores and mycelium of fungi and bacteria. Some of these bodies were found, however, in the open air.

The scaly and small round epithelia found in most rooms are in large quantity in hospital wards; and probably in cases where there is much expectoration or exposure of pus or puriform fluids to the air, the quantity would be still larger.

Considering that the pleuro-pneumonia of cattle is probably propagated through the pus and epithelium cells of the sputa passing into the air-cells of other cattle; that even in man there is evidence of a pneumonic or phthisical disease being contagious (Bryson—Cases in the Mediterranean Fleet), the floating of these cells in the air is worthy of all attention. It may explain some of those curious instances of phthisis being apparently communicated. In military granular conjunctivitis (gray granulations), the remarkable effect of ventilation in arresting the spread (Stromeyer) seems to show that we have here a similar case, and that ventilation acts by diluting, oxidising, and drying the cells thrown off from the conjunctivæ. In many other diseases somewhat similar conclusions can be drawn.

Products of Combustion.

The products of firing pass out into the atmosphere at large; those of lighting are for the most part allowed to diffuse in the room.

Coal of average quality gives off in combustion—

1. Carbon.—About 1 per cent. of the coal is given off as fine carbon and tarry particles.
2. Carbonic acid.—In Manchester, Angus Smith calculated some years ago that 15,000 tons of carbonic acid were daily thrown out.
3. Carbonic oxide.—The amount depends on the perfection of combustion.
4. Sulphur and sulphurous and sulphuric acids.—The amount of sulphur in coal varies from ½ to 6 or 7 per cent. In the air of Manchester, A. Smith found 1 grain of sulphuric acid in 2000 and 1076 cubic feet.
5. Sulphuret of carbon.
6. Ammonium sulphide, or carbonate.
7. Sulphuretted hydrogen (sometimes).
8. Water.

From some manufactories there pour out much greater quantities of SO_2 (copper-works), arsenical fumes, sulphuretted hydrogen, carbonic oxide, &c.

For complete combustion, 1 ℔ of coal demands about 240 cubic feet of air.

Wood produces carbonic acid and oxide and water in large quantity, but few compounds of sulphur. 1 ℔ of dried wood demands about 120 cubic feet of air for complete combustion.

Coal-gas, when fairly purified, is composed of—

Hydrogen,	40	to	45·58
Marsh gas (light carburetted hydrogen),	35	to	40
Carbonic oxide,	3	to	6·6
Olefiant gas (ethylene),	3	to	4
Acetylene,	2	to	3

Sulphuretted hydrogen,	0·29 to 1
Nitrogen,	2 to 2·5
Carbonic acid,	3 to 3·75
Sulphurous acid,	·5 to 1
Ammonia or ammonium sulphide,	(or in the best cannel-
Carbon bisulphide,	coal gas only traces).

In some analyses the carbonic oxide has been as high as 11 per cent., and the light carburetted hydrogen 56; in such cases the amount of hydrogen is small. As much as 60 grains of sulphur have been found in 100 cubic feet of gas.* The Parliamentary maximum is 20 grains in 100 cubic feet.

In badly purified gas there may be a great number of substances in small amount, especially hydrocarbons and alcohols, such as propylene, butylene, amylene, benzole, xylol, some of the nitrogenous oily bases, such as pyrrol, picoline, &c.†

When the gas is partly burnt, the hydrogen and light and heavy carburetted hydrogens are almost destroyed; nitrogen (67 per cent.), water (16 per cent.), carbonic acid (7 per cent.), and carbonic oxide (5 to 6 per cent.), with sulphurous acid and ammonia, being the principal resultants. And these products escape usually into the air of rooms. With perfect combustion there will be little carbonic oxide.

According to the quality of the gas, 1 cubic foot of gas will unite with from ·9 to 1·64 cubic feet of oxygen, and produces on an average 2 cubic feet of carbonic acid, and from ·2 to ·5 grains of sulphurous acid. In other words, 1 cubic foot of gas will destroy the entire oxygen of about 8 cubic feet of air. One cubic foot of gas will raise the temperature of 31,290 cubic feet of air 1° Fahr.

Oil.—A lamp with a moderately good wick burns about 154 grains of oil per hour, consumes the oxygen of about 3·2 cubic feet of air, and produces a little more than $\frac{1}{2}$ a cubic foot of carbonic acid; 1 ℔ of oil demands from 140 to 160 cubic feet of air for complete combustion.

A candle of 6 to the ℔ burns per hour about 170 grains.

The products of the combustion of coal and wood pass into the atmosphere at large, and usually are at once largely diluted. Even in the smoky air of Manchester, the carbonic acid does not exceed on an average the normal amount (Roscoe). Though on a very still day, Smith has found it as high as 1·2 per 1000, in London; on a windy day, it was ·3, and probably is not often above ·5. In Manchester, Roscoe found a mean of ·39 volumes per 1000. In a dense fog in Manchester the amount was ·6 per 1000. The mean amount for London was ·37 per 1000 volumes. In Paris, Boussingault calculated that the whole of the enormous amount of carbonic acid formed in 24 hours was dissipated in the same time. At Madrid, however, the observations of Ramon da Luna show that aeration is less complete, and that the amount of carbonic acid averages ·517, and may reach ·8 per 1000 volumes. Still, diffusion and the ever moving air rapidly purify the atmosphere from carbonic acid.

It is not so, however, with the suspended carbon and tarry matters, which are too heavy to drift far, or to ascend high. As a rule, the particles of carbon are not found higher than 600 feet; and the way it accumulates in the lower strata of the atmosphere can be seen by looking at any lofty building in London. The air of London is so loaded with carbon, that even when there is no fog, particles can be collected on Pouchet's aeroscope when only a very small quantity of air is drawn through.

* Chemical News, March 1865, p. 154.

† For a fuller list of these substances, which do not appear very important, see Pappenheim's Handbuch der San. Pol. band iii. Supp. p. 261.

Sulphurous and sulphuric acid also appear to be less rapidly removed, as Angus Smith found a very perceptible quantity in the air of Manchester; and the rain water is often made acid from this cause.

The products of gas combustion are for the most part allowed to escape into rooms, but certainly this should not be allowed, when gas is burnt in the large quantities commonly used. The immense quantity of gas often used causes great heat, humidity of the air, and there is also some sulphurous acid, an excess of carbonic, and, probably, a little carbonic oxide, to which some of the effects may be due. According to Dr Zock,* coal gas gives off rather more carbonic acid for an equal illuminating power than oil, but less than petroleum. Dr Odling found, for equal illuminating power, that candles gave more impurity to the air than gas.† Gas gives out, however, more water.

Products of Sewage Matter and Air of Sewers.

(See Chapter on Removal of Excreta.)

Air of Churchyards and Vaults.

The decomposition of bodies gives rise to a very large amount of carbonic acid. It has been calculated that when intramural burial was carried on in London, 2½ millions of cubic feet were disengaged annually from the 52,000 bodies then buried. Ammonia, and an offensive putrid vapour are also given off. The air of most cemeteries is richer in carbonic acid (·7 to ·9 per 1000, Ramon da Luna), and the organic matter is perceptibly large when tested by potassium permanganate.

In vaults, the air contains much carbonic acid, carbonate or sulphide of ammonium, nitrogen, hydrosulphuric acid, and organic matter. Waller Lewis found little SH_2 or CH; or cyanogen, or phosphoretted hydrogen. In his experiments the gas always extinguished flame.

Fungi and germs of infusoria abound.

Gases and Vapours given out from certain Trades.

Hydrochloric acid gas, from alkali works.

Sulphurous and sulphuric acids, from copper-works—bleaching.

Sulphuretted hydrogen, from several chemical works, especially of ammonia.

Carbonic acid, carbonic oxide, and sulphuretted hydrogen, from brick-fields and cement-works.

Carbonic oxide (in addition to above cases), from iron furnaces, gives rise to from 22 to 25 per cent. (Letheby); from copper furnaces, 15 to 19 per cent. (Letheby).

Organic vapours, from glue refiners, bone-burners, slaughter-houses, hackeries.

Zinc fumes (oxide of zinc), from brassfounders.

Arsenical fumes, from copper-smelting.

Bisulphide of carbon, from some india-rubber works.

Air of Marshes.

The air of typical marshes contains usually an excess of carbonic acid, which amounts, perhaps, to ·6 to ·8 or more per 1000 volumes. Watery vapour is usually in large quantity. Sulphuretted hydrogen is present, if the water of the marsh contains sulphates, which, in presence of organic matter, are con-

* Zeitsch. für Biol. band ii. p. 117 (1867).

† Medical Times and Gazette, Jan. 9. 1869.

verted into sulphurets, from which SH_2 is derived by the action of vegetable acids. Carburetted hydrogen is also often present, and occasionally free hydrogen and ammonia, and, it is said, phosphoretted hydrogen.

Organic matter also exists in considerable quantity. Discovered by Vauquelin (1810 and 1811, in the air collected over the Languedoc marshes by De Lisle), and again by Moscati (1818, in the air of a Lombardy rice-field), and examined more recently by Boussingault (1829, 1839), Gigot (1859), and Becchi (1861), the organic matter seems to have much the same character always. It blackens sulphuric acid when the air is drawn through it; gives a reddish colour to nitrate of silver; has a flocculent appearance, and sometimes a peculiar marshy smell, and, heated with soda-lime, affords evidence of ammonia. The amount in Becchi's experiments was ·00027 grammes in a cubic metre of air (= ·000118 grains in 1 cubic foot). Ozone, led through a solution of this organic matter, did not destroy it. Besides this organic matter, various vegetable matters and animals, floating in the air, are arrested when the air of marshes is drawn through water, or sulphuric acid, and debris of plants, infusoria, insects, and even, it is said, small crustacea are found; the ascensional force given by the evaporation of water seems, indeed, to be sufficient to lift comparatively large animals into the air. It has been stated that ozone is deficient in the air over marshes, but the observations of Burdel (Recherches sur les fièvres paludéennes, 1858) do not confirm this. He often found as much ozone as in other air. In the air collected from the surface of lakes, containing some aquatic plants, especially the Chara, there is a large proportion of oxygen, and this air gives, near the surface, the reaction of ozone (Clemens), while at some feet above the reaction is lost. This is usually ascribed to the oxidation of organic matter, which rises simultaneously from the water.

Air in the Holds of Ships.

The air in the holds of ships is compounded of exhalations from the wood, bilge-water, and cargo. Owing to the usual coolness, and comparative immobility of the air, it often becomes extremely foul. The composition is not known, but the smell of sulphuretted hydrogen is very perceptible, and white paint is blackened.

Air of Mines.

In the metalliferous mines the air, according to Angus Smith,* is poor in oxygen (20·5 per cent. sometimes), and very rich in carbonic acid (7·85 per 1000 volumes on a mean of many experiments). It also contains organic matter, giving, when burnt, the smell of burnt feathers, in uncertain amount. These impurities arise from respiration, combustion from lights, and from gunpowder blasting. This latter process adds to the air, in addition to carbonic acid, carbonic oxide, hydrogen and sulphuretted hydrogen, various solid particles, consisting of suspended salts, which may amount to as much as 3 grains in each cubic foot of air. These suspended substances are especially sulphate of potash, carbonate of potash, hyposulphite of potash, sulphide of potassium, sulphocyanide of potassium, nitrate of potash, carbon, sulphur, and sesquicarbonate of ammonia.

Fermentative or Septic Condition of the Atmosphere.

The observations of Schrœder, and especially of Pasteur, are likely to have a very important influence on the doctrines of Etiology. It must now be

* Report on Mines, Blue Book, 1864.

admitted that countless germs of vegetables and infusoria exist in the air, and develop whenever they find an appropriate nidus. The germs of *Bacterium termo* are in great abundance; those of the *Mycoderms*, *Mucidines*, and *Torulæ* are also very common. According to Pasteur, during this development they produce those chemical changes in the nidus, which have ordinarily been referred to the action of oxygen alone. Some of these infusorial ferments, such as the Bacteria, require oxygen for their action; others, like the Vibrios, develop only when there is no oxygen. In either case, all that they require is an organic menstruum, and then either the one set of ferments or the other comes into play, and either produces the fermentative changes and putrefaction, or invariably accompanies them. The amount of these germs in the air appears to be in proportion to the organic impurity of the atmosphere, since organic fermentable liquids change very slowly, or not at all, when exposed to calcined air, or to the pure mountain air,* but very rapidly when exposed to vitiated air. A putrid emanation, acting for a very short time, suffices alone to change milk (Sanderson), or to commence putrefaction in meat. According to Pasteur, different kinds of chemical changes are brought about by different germs; the alcoholic fermentations by the Torula; the acetous fermentation by the *Mycoderma aceti;* the lactic acid by another kind; the butyric acid fermentation, not by a vegetable but by a Vibrio, which can not only live without air, but dies in it.

The septic condition of the atmosphere, as Dr Burdon-Sanderson has termed it,† derives importance from the possibility of its being concerned in the production of some of the so-called zymotic diseases. On this point there is still so much doubt that nothing decided can be said of it.‡

These germs are not destroyed except at a high temperature. The *Bacterium termo* requires a heat of 212° Fahr. to kill it, and the spores of the Mucidines 240° Fahr. A temperature of 261° Fahr. kills all. Merely filtering the air, by drawing it through cotton wool, will cleanse it from many infusoria (Schrœder); and it seems highly probable that the explanation Professor Lister has given of the effect of carbolic acid in the treatment of open suppurating wounds is correct, and that the purification of the air from the floating germs is the explanation of the great success of his mode of treatment, which appears destined to work extraordinary changes in surgical practice.

SECTION II.

DISEASE PRODUCED BY IMPURITIES IN AIR.

Sub-Section I.—Suspended Matters.

1. *Mineral Substances.*—A considerable number of substances suspended in the atmosphere produce diseases from mere mechanical causes, such as ophthalmia or nasal catarrh, from irritation of dust, or bronchitis, from the inhalation of fine particles of coal, sand, steel, or other metal, flocks of cotton, flax, hemp, or fine dust; and dyspepsia, from similar substances being swallowed.§ The disease of the lungs appears in some cases to run the course

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* On this point Pasteur's observations have been denied by others (Pouchet, &c.), but the balance of evidence seems to be at present in his favour.

† Review on the Hygiene of Habitations, in the Brit. and For. Med. Chir. Rev., Oct. 1861.

‡ A short notice of the evidence on the production of "splenic apoplexy," by Bacteria, will be found in my Review on Hygiene, in the 8th volume of the Report of the Army Medical Department (1868).

§ Thackrah enumerates the following trades—The Effects of Arts, Trades, and Professions

of phthisis, but in many instances it is chronic bronchitis, followed by emphysema. A large number of the unhealthy trades are chiefly so from this cause; this is the case in fact with miners of all kinds. Mr Simon* states that, with one exception, the 300,000 miners in England break down as a class prematurely from bronchitis and pneumonia, caused by the atmosphere in which they live. The exception is most important. The colliers of Durham and Northumberland, where the mines are well ventilated, do not appear to suffer from an excess of pulmonary disease, or do so in a slight degree.

In different mines, also, the amount of pulmonary disease is different, apparently according to the amount of ventilation.

The following table by the Registrar-General is printed in the Report of the Commissioners on Mines, Blue-book, 1864.

Average Annual Deaths per 1000 *from Pulmonary Disease, during the years* 1860–62 *inclusive.*

Ages.	Metal Miners in Cornwall.	Metal Miners in Yorkshire.	Metal Miners in Wales.	Males, exclusive of Miners, in Yorkshire.
Between 15 and 25 years,	3·77	3·40	3·02	3·97
,, 25 ,, 35 ,,	4·15	6·40	4·19	5·15
,, 35 ,, 45 ,,	7·89	11·76	10·62	3·52
,, 45 ,, 55 ,,	19·75	23·18	14·71	5·21
,, 55 ,, 65 ,,	43·29	41·47	35.31	7·22
,, 65 ,, 75 ,,	45·04	53·69	48·31	17·44

The enormous increase of lung diseases among the miners after the age of 35, is seen at a glance.

In the pottery trade all classes of workmen are exposed to dust, especially, however, the flat-pressers. So common is emphysema that it is called "the potters' asthma."

So also among the china scourers; the light flint dust disengaged in great quantities is a "terrible irritant." Dr Greenhow states that *all* sooner or later become "asthmatical."

The grinders of steel, especially of the finer tools, are perhaps the most fatally attacked of all, though of late years the evil has been somewhat lessened by the introduction of wet-grinding in some cases, by the use of ventilated wheel-boxes, and by covering the work with linen covers when practicable. The wearing of masks and coverings for the mouth appears to be inconvenient, otherwise there is no doubt that a great amount of the dust might be stopped by very simple contrivances.†

Button-makers, especially the makers of pearl buttons, also suffer from chronic bronchitis, which is often attended with hæmoptysis. So also pin

on Health, 1832, p. 63:—The workmen who were affected injuriously by the dust of their trades 30 years ago even, and the same list will almost do for the present day: Corn-millers, maltsters, teamen, coffee-roasters, snuff-makers, papermakers, flock-dressers, feather-dressers, shoddy-grinders, weavers of coverlets, weavers of harding, dressers of hair, hatters employed in the bowing department, dressers of coloured leather, workers in flax, dressers of hemp, some workers in wood, wiregrinders, masons, colliers, iron miners, lead miners, grinders of metals, file cutters, machine-makers, makers of firearms, button-makers.

* Fourth Report of the Medical Officer of the Privy Council, 1862, p. 15, *et seq.* See also Aldridge in B. and F. Med. Chir. Rev. July 1864, for the effects of the pottery trade.

† See for further particulars and much interesting information Dr Hall's paper read at the Social Science Congress in 1865.

pointers; some electro-plate workmen, and many other trades of the like kind, are more or less similarly affected.

In some of the textile manufactures much harm is done in the same way. In the carding rooms of cotton and wool spinners, there is a great amount of dust and flue, and the daily grinding of the engines disengages also fine particles of steel.

In flax factories a very irritating dust is produced in the process of hackling, carding, line preparing, and tow spinning. Of 107 operatives, whose cases were taken indiscriminately by Dr Greenhow, no less than 79 were suffering from bronchial irritation, and in 19 of these there had been hæmoptysis. Among 27 hacklers, 23 were diseased.* These evils appear to be entirely and easily preventable.

The makers of grinding-stones suffer in the same way; and children working in the making of sand-paper are seriously affected, sometimes in a very short time, by the inhalation of fine particles of sand into the lungs.

In making Portland cement, the burnt masses of cement are ground down, and then the powder is shovelled into sacks; the workmen doing this cough a great deal, and often expectorate little masses of cement. I have been informed by some of them that if they had to do the same work every day, it would be impossible to continue it on account of the lung affection.

In making bichromate of potash, the heat and vapour employed carry up fine particles, which lodge in the nose and cause great irritation, and finally ulceration, and destruction of both mucous membrane and bone. Those who take snuff escape this. The mouth is not affected, as the fluids dissolve and get rid of the salt. The skin is also irritated if the salt is rubbed on it, and fistulous sores are apt to be produced. No effect is noticed to be produced on the lungs.† Washing the skin with subacetate of lead is the best treatment.

At present it would appear that the nature of the suspended substance has little influence; the quantity, fineness, and irritating properties (depending probably on the sharp angles of the particles) appear to be the important points.

In the process of sulphuring vines the eyes often suffer, and sometimes (especially when lime is used with the sulphur) decided bronchitis is produced.

In some trades, or under special circumstances, the fumes of metals, or particles of metallic compounds, pass into the air. Brassfounders suffer from bronchitis and asthma as in other trades in which dust is inhaled; but in addition, they also suffer from the disease described by Thackrah as "brass ague," and by Dr Greenhow as "brassfounders' ague." It appears to be produced by the inhalation of fumes of oxide of zinc; the symptoms are tightness and oppression of the chest, with indefinite nervous sensations, followed by shivering, an indistinct hot stage, and profuse sweating. These attacks are not periodical.

Coppersmiths are affected somewhat in the same way, by the fumes arising from the partly volatilised metal, or from the spelter (solder).

Tinplate workers also suffer occasionally from the fumes of the soldering.

Plumbers inhale the volatilised oxide of lead which rises during the process of casting. Nausea and tightness of the chest are the first symptoms, and then colic and palsy.

Manufacturers of white lead inhale the dust chiefly from the white beds and the packing.

House painters also inhale the dust of white lead to a certain extent, though in these, as in former cases, much lead is swallowed from want of cleanliness of the hands in taking food.

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* Mr Simon's Fourth Report, p. 19. † Chevallier, Ann. d'Hygiène, July 1863, p. 83.

Workers in mercury, silverers of mirrors, and water gilders (men who coat silver with an amalgam of mercury and gold), are subject to mercurialismus.

Workmen who use arsenical compounds, either in the making of wall papers or of artificial flowers, &c., suffer from slight symptoms of arsenical poisoning, and many persons who have inhaled the dust of rooms papered with arsenical papers have suffered from both local and constitutional effects; the local being smarting of the gums, eyes, nose, œdema of the eyelids, and little ulcers on the exposed parts of the body; the constitutional being weakness, fainting, asthma, anorexia, thirst, diarrhœa, and sometimes even severe nervous symptoms. Arsenic has been detected in the urine of such persons.

2. *Germs of Infusoria, Fungi, Algæ, Pollen of Flowers, &c. in the Air.*—The speculations which have attributed the spread of epidemic diseases to the action of fungi* have regained interest since the investigations of Schrœder. The same physician has endeavoured to show that ague is produced by Palmella, while others, with perhaps more truth, have attributed ague to Oscillarinicæ.† The production of hay asthma by the effluvia from the *Anthoxanthum oderatum*, and other vegetable effluvia (pollen?), is now generally believed in. At present it can scarcely be said that this subject of propagation of the epidemic diseases by plants has passed out of the realm of conjecture.

Dr Salisbury‡ of Ohio has affirmed that the prevalence of measles in the Federal army arose from fungi on mouldy straw. He inoculated himself, his wife, and forty other persons with the fungi, and produced a disease like measles in from 24 to 96 hours. It is stated also that this disease was protective against measles. Dr Woodward (United States Army) has repeated Dr Salisbury's experiments, and does not confirm them.

3. *Organic Substances.*—The most important class of diseases produced by impurities in the atmosphere is certainly caused by the presence of organic matters floating in the air, since under this heading come all the specific diseases. The exact condition of the organic matter is unknown; whether it is in the form of impalpable particles, or moist or dried epithelium and pus cells, is a point for future inquiry; and whether it is always contained in the substances discharged or thrown off from the body (as is certainly the case in smallpox), or is produced by putrefactive changes in those discharges, as is supposed to be the case in cholera and dysentery, is also a matter of doubt. The modern expositors of the old doctrine of fomites would consider these organic matters to be inconceivably minute particles of living, or to use Dr Beale's phrase, germinal matter, which is capable, he believes, of wonderfully rapid growth under proper conditions.§ But, from the way in which, in many cases, organic substances in the air are absorbed by hygroscopic bodies, it would appear that it is often combined with, or is at any rate condensed with, the water of the atmosphere.

The specific poisons manifestly differ in the ease with which they are oxidised and destroyed. The poison of typhus exanthematicus is very readily got rid of by free ventilation, by means of which it must be at once diluted and oxidised, so that a few feet give, under such circumstances, sufficient protection. This is the case also with the poison of oriental plague; while, on the other hand, the poisons of smallpox and scarlet fever will spread in

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* I refer to the speculations of Adam Neale, Cowdell, Mitchell, Holland, and others.

† Camp Diseases in the U.S. Army, p. 278. The fungus is a Penicillium. Dr Wood (Professor of Botany in the University of Philadelphia) has advanced (Amer. Journal of Med. Sci. 1868) some extremely strong botanical arguments against the view that malarial diseases can be owing to Palmella.

‡ American Journal of the Medical Sciences, July 1862.

§ For a very interesting exposition of this theory, see Dr Morris' "Germinal Matter and the Contact Theory," 2d edition, 1867.

spite of very free ventilation, and retain their power of causing the same disease for a long time; even it may be for weeks, or in the case of scarlet fever, for months. The poison of cattle-plague has been known to retain its potency for weeks, perhaps for months. Is it that in one case the poison is a mere cloud of molecules; that in the other it is contained in epithelium and pus cells, thrown off from the skin in both cases, and from the throat also in one; and which adhering to walls, clothes, &c., partially dry, and then can be rendered again active by warmth and moisture?

In the case of malaria, the process of oxidation must be slow, since the poison can certainly be carried for many hundred yards; even sometimes for more than a mile in an upward direction (up a ravine for instance), or horizontally if it does not pass over the surface of water. The poison of cholera also, it is supposed, can be blown by the winds for some distance; but the most recent observations on its mode of spread lead to the conclusion that the portability of the poison in this way has been overrated.

But organic matters carrying the specific poisons are not the only suspended substances which thus float through the atmosphere.

There can be no doubt that while purulent and granular ophthalmia most frequently spreads by direct transference of the pus or epithelium cells, by means of towels, &c., and that erysipelas and hospital gangrene, in surgical wards, are often carried in a similar way, by dirty sponges and dressings, another mode of transference is by the passage into the atmosphere of disintegrating pus cells and putrefying organic particles, and hence the great effect of free ventilation in military ophthalmia (Stromeyer), and in erysipelas and hospital gangrene. In both these diseases, great evaporation from the walls or floor seems in some way to aid the diffusion, either by giving a great degree of humidity, or in some other way. The practice of frequently washing the floors of hospitals is well known to increase the chance of erysipelas.

It is a question even whether we shall not be obliged to extend this view, and to believe that every pus or epithelium cell, or even formless organic substance, floating in the air, may, if it find a proper place or nidus in or on which it can be received, communicate to it its own action, and thus act as a true contagium.

Sub-Section II.—Gaseous Matters.

(*a.*) *Carbonic Acid.*—The normal quantity of carbonic acid being ·4 volumes per 1000, it produces fatal results when the amount reaches from 50 to 100 per 1000 volumes; and at an amount much below this, 15 or 20 per 1000, it produces, in some persons at any rate, severe headache. Other persons can inhale, for a brief period, considerable quantities of carbonic acid without injury;* and animals can be kept for a long time in an atmosphere highly charged with it, provided the amount of oxygen be also increased. Probably, indeed, discomfort, indicating the commencement of poisoning, is produced by a quantity below this; but sufficient experiments to show the precise effect of small quantities of carbonic acid, unmixed with other gaseous substances, in different persons, are yet wanting. In the air of respiration, headache and vertigo are produced when the amount of carbonic acid is not more than 1·5 to 3 volumes per 1000; but then organic matters, and possibly other gases, are present in the air, and the amount of oxygen is also lessened. Well-sinkers, when not actually disabled from continuing their work by carbonic acid, are often affected by headache, sickness, and loss of appetite; but the amount of carbonic acid has never been determined.

* It is stated that Dr Christison has employed air containing 20 per cent. of carbonic acid as an anæsthetic. (Taylor's Jurisprudence, 1865, p. 713.)

The effect of constantly breathing an atmosphere containing an excess of carbonic acid (up to 1 or 1·5 per 1000 volumes) is not yet perfectly known. Dr Angus Smith* has attempted to determine the effect of carbonic acid *per se*, the influence of the organic matter of respiration being eliminated. He found that 30 volumes per 1000 caused great feebleness of the circulation, with usually slowness of the heart's action; the respirations were, on the contrary, quickened, but were sometimes gasping. These effects lessened when the amount of carbonic acid was smaller, but were perceptible when the amount was as low as 1 volume per 1000—an amount often exceeded in dwelling-houses. At the same time, this is not the case always, for in the air of a soda-water manufactory, where the carbonic acid was 2 per 1000, Smith found no discomfort to be produced. It has been supposed that lung diseases, especially phthisis, are produced by it; but as this opinion has been drawn merely from the effects of the air of respiration, which is otherwise vitiated, it cannot be considered to stand on any sure basis.

The presence of a large amount of carbonic acid in the air may lessen the elimination of carbonic acid from the lungs, and thus retain the gas in the blood, and in time possibly produce serious alterations in nutrition.

(*b.*) *Carbonic Oxide.*—Of the immense effect of carbonic oxide, there is no doubt. Less than one-half per cent. has produced poisonous symptoms, and more than one per cent. is rapidly fatal to animals. It appears from Bernard's, and from Lothär Meyer's observations,† that the carbonic oxide, volume for volume, completely replaces the oxygen in the blood, and cannot be again displaced by oxygen, so that the person dies asphyxiated; but Pokrowsky has shown‡ that the carbonic oxide may gradually be converted into carbonic acid, and be in that way got rid of. It seems, in fact, as Hoppe conjectured, to completely paralyse, so to speak, the red particles, so that they cannot any longer be the carriers of oxygen. The observations of Dr Kleber § show that, in addition to loss of consciousness and destruction of reflex action, the carbonic oxide causes complete atony of the vessels, diminution of the vascular pressure, and slowness of circulation, and finally, paralysis of the heart. A very rapid parenchymatous degeneration takes place in the heart and muscles generally, and in the liver, spleen, and kidneys.

(*c.*) *Sulphuretted Hydrogen.*—The evidence with regard to sulphuretted hydrogen is contradictory. While dogs and horses are affected by comparatively small quantities (1·25 and 4 volumes per 1000 volumes of air, and suffer from purging and rapid prostration), men can breathe a larger quantity. Parent-Duchâtelet inhaled an atmosphere containing 29 volumes per 1000 for some short time.||

When inhaled in smaller quantities, and more continuously, it has appeared in some cases harmless, in others hurtful. Thackrah, in his inquiries, could trace no bad effect. It is said that in the Bonnington chemical works, where the ammoniacal liquor from the Edinburgh gas-works is converted into sulphate and chloride of ammonium, the workmen are exposed to the fumes of hydro-sulphate of ammonia, and of hydro-sulphuric acid, to such an extent that coins are blackened; yet no special malady is known to result. The same observations have been made at the Britannia metal-works, where a superficial deposit of sulphuret is decomposed with acids.

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* Chemical News, Feb. 1865.

† De Sanguine Oxydo Carbonico Infecto, 1858. Reviewed in "Virchow's Archiv," band xv. p. 389. See also Letheby, "Chemical News," April 1862.

‡ Virchow's Archiv, band xxx. p. 525 (1864).

§ Ibid. band xxxii. p. 450 (1865).

|| On dogs, Herbert Barker found a larger quantity necessary than that stated above; viz., 4·29 per 1000 is rapidly fatal; 2·06 per 1000 may be fatal; but ·5 per 1000 may produce serious symptoms.

So large a quantity of SH_2 is given out from some of the salt marshes at Singapore, that slips of paper moistened in acetate of lead are blackened in the open air, yet, not only is no bad effect found to ensue, but Dr Little has even conjectured (on very disputable grounds, however) that the SH_2 may neutralise the marsh miasma.

On the other hand, some of the worst marshes in Italy are those in which SH_2 exists in large quantity in the air, and, in direct opposition to Little, it has been supposed that the highly poisonous action of the marsh gas is partly owing to the sulphuretted hydrogen. Again, in the making of the Thames Tunnel, the men were exposed to SH_2, which was formed from the decomposition of iron pyrites; after a time they became feeble, lost their appetites, and finally passed into a state of great prostration and anæmia. Nor, as far as is known, was there anything to account for this except the presence of sulphuretted hydrogen.*

Dr Josephson and Rawitz† have also investigated in mines effects produced apparently by sulphuretted hydrogen; two forms of disease are produced—pure narcotic, and convulsive and tenanic symptoms. In the first case, the men became pale, the extremities got cold. There was headache, vertigo, a small weak pulse, sweating, and great loss of strength. On this, spasms and tremblings sometimes followed, and even tetanus. These symptoms were acute, and not, as in the Thames Tunnel case, chronic. When these attacks occurred, the temperature was high and the air stagnant.

The observations of Clemens, also, on the development of boils from the passage of SH_2 into the drinking water from the air, if not convincing, cannot be overlooked. (See page 79.)‡

The symptoms produced by ammonium sulphide in dogs are said, by Herbert Barker,§ to differ from those of SH_2. There is vomiting without purging, quickened pulse, and heat of skin, followed by coldness and rapid sinking. When sulphuretted hydrogen and ammonium sulphide, dissolved in water, are injected into the blood,|| they, and especially SH_2, produce the same symptoms as the injection of non-corpuscular putrid fluids, viz., profuse diarrhœal evacuations, with sometimes marked choleraic symptoms and decided lowering of the temperature of the body, congestions of the lungs, liver, spleen, and kidneys, irritation of the spine, and opisthotonos. But, in this case, a much larger quantity will be introduced than by inhalation through the lungs.

(*d.*) *Carburetted Hydrogen.*—A large quantity of carburetted hydrogen can be breathed for a short time; as much, perhaps, as 200 to 300 volumes per 1000. Above this amount it produces symptoms of poisoning, headache, vomiting, convulsions, stertor, dilated pupil, &c.

Breathed in small quantities, as it constantly is by some miners, it has not been shown to produce any bad effects; but here, as in so many other cases, it is to be wished that a more careful examination of the point were made. Without producing any marked disease, it may yet act injuriously on the health.

(*e.*) *Ammoniacal Vapours.*—An irritating effect on the conjunctiva seems to be the most marked effect of the presence of these vapours. I am not aware of any evidence showing any other effect on the health.

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* Taylor's Med. Jurisp. 1865, p. 727.

† Schmidt's Jahr. band cx. p. 334, and band cxvii. p. 85.

‡ I notice, in the account of the new Laboratory at Leipsig, that Kolbe has made a special arrangement for the supply of SH_2 from gasometers, as the custom of each man making the gas himself evolves so much that the health of all who are working in the room suffers. (Das Neue Chem. Lab. von Univ. Leipzig, p. 20).

§ On Malaria and Miasmata, p. 212.

|| Weber, Syd. Soc. Year-Book for 1864, p. 227.

(*f.*) *Sulphurous Acid Gas.*—The bleachers in cotton and worsted manufactories, and storers of woollen articles, are exposed to this gas, the amount of which in the atmosphere is, however, unknown. The men suffer from bronchitis, and are frequently sallow and anæmic.

When sulphurous acid is evolved in the open air, and therefore at once largely diluted, as in copper smelting, it does not appear to produce any bad effects in men, though from being washed down with rain, it affects herbage, and, through the herbage, cattle, causing affections of the bones, falling off of the hair, and emaciation.

(*g.*) *Hydrochloric Acid Vapours* in large quantities are very irritating to the lungs; when poured out into the air, as was formerly the case in the alkali manufactures, they are so diluted as apparently to produce no effect on men, but they completely destroy vegetation. In some processes for making steel, hydrochloric, sulphurous and nitrous acids, and chlorine are all given out, and cause bronchitis, pneumonia, and destruction of lung tissue, as well as eye diseases.*

(*h.*) *Carbon Bisulphide.*—In certain processes in the manufacture of vulcanised india-rubber a noxious gas is given off, supposed to be the vapour of carbon bisulphide. It produces headache, giddiness, pains in the limbs, formication, sleeplessness, nervous depression, and complete loss of appetite. Sometimes there is deafness, dyspnœa, cough, febrile attacks, and sometimes even amaurosis and paraplegia (Delpech). The effects seem due to a direct anæsthetic effect on the nervous tissue.

Sub-Section III.—Effect of Air Impure from several Substances always Co-Existing.

The examination of the effects of individual gases, however important, can never teach us the results which may be produced by breathing air rendered foul by a mixture of impurities. The composite effect may possibly be very different from what would have been anticipated from a knowledge of the action of the isolated substances.

(*a*) *Air rendered Impure by Respiration* (see page 89).—The effect of the fœtid air containing organic matter, excess of water and carbonic acid, produced by respiration, is very marked upon many people; heaviness, headache, inertness, and in some cases nausea, are produced. From experiments on animals in which the carbonic acid and watery vapour were removed, and organic matter alone left, Gavarret and Hammond have found that the organic matter is highly poisonous. Hammond found that a mouse died in forty-five minutes, and I have known cases in which the inhalation of such an atmosphere for three or four hours produced in men decided febrile symptoms (increased temperature, quickened pulse, furred tongue, loss of appetite, and thirst), for even twenty-four or forty-eight hours subsequently.

When the air is rendered still more impure than this, it is rapidly fatal, as in the cases of the Black Hole at Calcutta; of the prison in which 300 Austrian prisoners were put after the battle of Austerlitz (when 260 died very rapidly); and of the steamer Londonderry. The poisonous agencies are probably the organic matter and the deficient oxygen, as the symptoms are not those of pure asphyxia. If the persons survive, a febrile condition is left behind, which lasts three or four days, or there are other evidences of affected nutrition, such as boils, &c.

When air more moderately vitiated by respiration is breathed for a longer

* Jordan—Canstatt's Jahresb. for 1863, band vii. p. 76.

period, and more continuously, its effects become complicated with those of other conditions. Usually a person who is compelled to breathe such an atmosphere is at the same time sedentary, and, perhaps, remains in a constrained position for several hours, or possibly is also under-fed or intemperate. But allowing the fullest effect to all other agencies, there is no doubt that the breathing the vitiated atmosphere of respiration has a most injurious effect on the health.* Persons soon become pale, and partially lose their appetite, and after a time decline in muscular strength and spirits. The aeration and nutrition of the blood seem to be interfered with, and the general tone of the system falls below par. Of special diseases it appears pretty clear that pulmonary affections are more common.

Such persons do certainly appear to furnish a most undue percentage of phthisical cases. The production of phthisis from impure air (aided most potently, as it often is, by coincident conditions of want of exercise, want of good food, and excessive work) is no new doctrine. Baudelocque long ago asserted that impure air is the great cause of scrofula (phthisis), and that hereditary predisposition, syphilis, uncleanness, want of clothing, bad food, cold and humid air, are by themselves non-effective. Carmichael, in his work on scrofula (1810), gives some most striking instances, where impure air, bad diet, and deficient exercise concurred together to produce a most formidable mortality from phthisis. In one instance, in the Dublin House of Industry, where scrofula was formerly so common as to be thought contagious, there were in one ward, 60 feet long and 18 feet broad (height not given), 38 beds, each containing four children; the atmosphere was so bad that in the morning the air of the ward was unendurable. In some of the schools examined by Carmichael, the diet was excellent, and the only causes for the excessive phthisis were the foul air and want of exercise. This was the case also in the house and school examined by Neil Arnott in 1832. Lepelletier (Traité Complet de la Maladie Scrophuleuse) also records some good evidence. Professor Alison, of Edinburgh, and Sir James Clark, in his invaluable work, lay great stress on it. Neil Arnott, Toynbee, Guy, and others brought forward some striking examples before the Health of Towns Commission (First Report, 1844, vol. i. pp. 52, 60, 69, 79, &c.). Dr Henry Cormac has insisted with great cogency on this mode of origin of phthisis; and Dr Greenhow, in his "Report on the Health of the People of England," also enumerates this cause as occupying a prominent place.†

In prisons, the great mortality which formerly occurred from phthisis, as for example at Millbank (Baly), seemed to be owing to bad air, conjoined with inferior diet and moral depression.

Two Austrian prisons, in which the diet and mode of life were, it is believed, essentially the same, offer the following contrast:—

In the prison of Leopoldstadt, at Vienna, which was very badly ventilated, there died in the years 1834–1847, 378 prisoners out of 4280, or 86 per 1000, and of these no less than 220, or 51·4 per 1000, died from phthisis; there were no less than 42 cases af acute miliary tuberculosis.

In the well-ventilated House of Correction in the same city, there were in five years (1850–1854) 3037 prisoners, of whom 43 died, or 14 per 1000, and

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* See among a number of other instances Guy's evidence before the Health of Towns Commission, vol. i. p. 89, *et seq.*, and S. Smith, ibid. p. 37, *et seq.*

† The observations of the development of what are apparently tubercular lesions from the circulation in the blood of pus or septic matter derived from inoculation in guinea pigs, by Burdon, Sanderson, and Wilson Fox, seem to give some support to the conjecture, that in these cases of tubercle from foul air, some corpuscular substances may be drawn into, and set up disease of, the lungs.

of these 24, or 7·9 per 1000, died of phthisis. The comparative length of sentences is not given, but no correction on this ground, if needed, could account for this discrepancy. The great prevalence of phthisis in some of the Indian gaols appears to be owing to the same cause, combined with insufficient diet.

The now well-known fact of the great prevalence of phthisis in most of the European armies (French, Prussian, Russian, Belgian, and English) can scarcely be accounted for in any other way than by supposing the vitiated atmosphere of the barrack-room to be chiefly in fault. This is the conclusion to which the Sanitary Commissioners for the Army came in their celebrated report. And if we must also attribute some influence to the pressure of ill-made accoutrements, and to the great prevalence of syphilis, still it can hardly be doubted that the chief cause of phthisis among soldiers has to be sought somewhere else, when we see that with very different duties, a variable amount of syphilis, and altered diet, a great amount of phthisis has prevailed in the most varied stations of the army, and in the most beautiful climates; in Gibraltar, Malta, Ionia, Jamaica, Trinidad, Bermuda, &c. (see history of these stations), in all which places the only common condition was the vitiated atmosphere which our barrack system everywhere produced. And, as if to clench the argument, there has been of late years a most decided decline in phthisical cases in these stations, while the only circumstance which has notably changed in the time has been the condition of the air. So also the extraordinary amount of consumption which prevails among the men of the Royal and Merchant Navies, and which, in some men-of-war, has amounted to a veritable epidemic, is in all probability attributable to the faulty ventilation.*

The deaths from phthisis in the Royal Navy averaged (3 years) 2·6 per 1000 of strength, and the invaliding 3·9 per 1000. The amount of consumption and of all lung diseases was remarkably different in the different ships. These inferences have received the strongest corroboration from the outbreak of a lung disease leading to the destruction of lung tissue in several of the ships on the Mediterranean station in 1860. Dr Bryson traces this clearly to contamination of the air, and notices that in several cases the disease appeared to be propagated from person to person.† It may be inferred that pus cells were largely thrown off during coughing, and, floating through the air were received into the lungs of other persons.

The production of phthisis in animals confirms this view. The case of the monkeys in the zoological gardens, narrated by Dr Arnott, is a striking instance. Cows in close stables frequently die from phthisis, or at any rate from a destructive lung disease (not apparently pleuro-pneumonia); while horses, who in the worst stables have more free air, and get a greater amount of exercise, are little subject to phthisis. But not only phthisis may reasonably be considered to have one of its modes of origin in the breathing an atmosphere contaminated by respiration, but other lung diseases, bronchitis and pneumonia, appear also to be more common in such circumstances. Both among seamen and civilians working in confined close rooms, who are otherwise so differently circumstanced, we find an excess of the acute lung affections. The only circumstance which is common to the two classes is the impure atmosphere. (Compare especially Gavin Milroy and Greenhow.) The favourite belief that these diseases are caused by transitions of temperature and exposure to weather, has been carried too far.

* Statistical Reports on the Health of the Navy, and especially Gavin Milroy's pamphlet on "The Health of the Royal Navy," 1862, pp. 44 and 54.

† Trans. of the Epidem. Soc. vol. ii. p. 142.

In addition to a general impaired state of health arising, probably, from faulty aeration of the blood, and to phthisis and other lung affections which may reasonably be believed to have their origin in the constant breathing of air vitiated by the organic vapours and particles arising from the person, it has long been considered, and apparently quite correctly, that such an atmosphere causes a more rapid spread of several specific diseases, especially typhus exanthematicus, plague, smallpox, scarlet fever, and measles. This may arise in several ways; the specific poison may simply accumulate in the air so imperfectly changed, or it may grow in it (for though there may be an analogical argument against such a process, it has never been disproved, and is evidently not impossible); or the vitiated atmosphere may simply render the body less resisting or more predisposed.

(*b.*) *Air rendered Impure by Exhalations from the Sick.*—The air of a sick-ward, containing as it does an immense quantity of organic matter, is well known to be most injurious. The severity of many diseases is increased, and convalescence is greatly prolonged. This appears to hold true of all diseases, but especially of the febrile. At a certain point of impurity, erysipelas and hospital gangrene appear. The occurrence of either disease is, in fact, a condemnation of the sanitary condition of the ward. It has been asserted that hospital gangrene is a precursor of exanthematic typhus, but probably the introduction at a particular time of the specific poison of typhus was a mere coincidence. But, doubtless, the same foul state of the air which aids the spread of the one disease would aid also that of the other.

When hospital gangrene has appeared, it is sometimes extremely difficult to get rid of it. Hammond* states that in a ward of the New York City Hospital, where hospital gangrene had appeared, removal of the furniture and patients did not prevent fresh patients being attacked. Closing the ward for some time and whitewashing had no effect. The plastering was then removed, and fresh plaster applied, but still cases recurred. At last the entire walls were taken down and rebuilt, and then no more cases occurred.

It is now well known that by the freest ventilation, *i.e.*, by treating men in tents or in the open air, hospital gangrene can be entirely avoided.† The occurrence of hospital gangrene in a tent is a matter of the rarest occurrence.

(*c.*) *Air rendered Impure by Combustion.*—Of the products of combustion which pass into the general atmosphere (see page 92), the carbonic acid and carbonic oxide are so largely and speedily diluted that it is not likely they can have any influence on health. The particles of carbon and tarry matter, and the sulphurous acid, must be the active agents if any injury results. It has been supposed that molecular carbon and sulphurous acid, instead of being injurious, may even be useful as disinfectants, and we might *a priori* conclude that to a certain extent they must so act, but certainly there is no evidence that the smoky air of our cities, or of our colliery districts, is freer from the poisons of the specific diseases than the air of other places. It has been supposed, indeed, that the air of large cities is particularly antagonistic to malaria, but there are probably other causes acting here. The solid particles of carbon, and the sulphurous acid gas, may, on the other hand, have injurious effects. It is not right to ignore the mechanical effect of the fine powder of coal so constantly drawn into the lungs, and even the possibility of irritation of the lungs from sulphurous acid. Certain it is, that

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* On Hygiene, p. 172.

† See Chapter on Hospitals, and Professor Jüngken's Address on Pyæmia in the Sydenham Society's Year-Book for 1862, p. 213, and Report on Hygiene by the Author, in the Army Medical Report for 1862 (vol. iv.)

persons with bronchitis and emphysema often feel at once the entrance into London atmosphere, and individual experience will, I believe, lead to the opinion that such an atmosphere has some effect in originating attacks of bronchitis, and in delaying recovery. But statistical evidence of the effect of smoky town atmospheres in producing lung affections on a large scale cannot be given, so many are the other conditions which complicate the problem.

The effect of breathing the products of combustion, of gas especially, is more easily determined. In proportion to the amount of contamination of the air, many persons at once suffer from headache, heaviness, and oppression. Bronchitic affections are frequently produced, which are often attributed to the change from the hot room to the cold air, but are really probably owing to the influence of the impure air of the room on the lungs.

The effects of constantly inhaling the products of gas combustion may be seen in the case of workmen whose shops are dark, and who are compelled to burn gas during a large part of the day; the pallor, or even anæmia and general want of tone which such men show, is owing to the constant inhalation of an atmosphere so impure.

(*d.*) *Air rendered Impure by Sewage Gas.*—Cases of asphyxia from sulphuretted hydrogen, sulphide of ammonium, carbonic acid, and nitrogen (or possibly rapid poisoning from organic vapours), occasionally occur both in sewers and from the opening of old cesspools. In a case at Clapham, the clearing out a privy produced in twenty-three children violent vomiting and purging, headache, and great prostration, and convulsive twitchings of the muscles. Two died in twenty-four hours.—("Health of Towns Report," vol. i. p. 139.)

If such cases as these are put aside, and we demand what is the condition of health of those who work in non-infected sewers, to use Parent-Duchâtelet's expression, we find some difference of opinion. Thackrah states* that sewer-men are not subject to any disease (apart from asphyxia), and are not short-lived. He cites no evidence. Parent-Duchâtelet† came on the whole to the same conclusion as regards the sewer-men of Paris in 1836. He says that there are some men so affected by the air of sewers that they can never work in them; but those who can remain suffer only from a little ophthalmia, lumbago, and perhaps sciatica. They consider otherwise their occupation not only innocent, but as favourable to health. The only fact adverse to this seemed to be that the air of the sewer greatly aggravated the venereal disease, and those who persisted in working with this disease on them inevitably perished.‡ The working in deep, old sewage matter produced an eruption on the parts bathed by the mud, which resembled itch sometimes, or was phlyctenoid in character.

When Parent-Duchâtelet's facts are subjected to analysis, the case is not, however, so clear as would appear from his statement. At one place he speaks of 24 men being the number of sewer-men, at another of 32—either number being too small for safe conclusions. He also gives a list (t. i. p. 386) of the 32 men, from which it appears that there were no less than 20 men who had only been employed six months in the sewers, and seven others who had only been there a year; two others had been less than sixteen months, and only three were over two years (viz., fifteen years and six years respectively). So that the extremely short period of time seems quite to vitiate any conclusions. But it appears also that a very considerable effect was produced on a large

* The Effects of Arts, Trades, and Professions on Health, 1832, p. 118.
† Hygiène Publique, vol. i. p. 247 (1836).
‡ Ibid. vol. i. p. 256.

number of these men, as, besides ophthalmia, from which no less than 25 of them had suffered, and several three and four times, 10 of the 20 men who had been employed less than six months had suffered from bilious and cerebral affections, diarrhœa, colics, jaundice, lumbar pains, and, in one case, bilious and cerebral fever. Of the seven men who had been employed less than one year, no less than three had suffered from colics and diarrhœa, and two from rheumatism. So that all the facts show that this celebrated evidence of Parent-Duchâtelet, which has been so often quoted to prove the innocuousness of sewer air, has been completely misunderstood, and that it rather proves the hurtfulness than otherwise. The principal affections seem to have been ophthalmia, bilious affections, diarrhœa, and colics. The exact amount of sickness per annum, the rate of mortality, and the expectation of life, have not been determined by any observer.

It must be remembered also that sewer air is of no invariable composition, that often, with good ventilation, it is tolerably pure, and that, in many cases, the inhabitants of houses over sewers really receive more sewer air than those who penetrate into the sewers themselves. The workmen also take great precautions, both in London and Paris, and, in both cases, the sewage matter is mixed with a very large quantity of water, which has a great effect in holding back deleterious products. Occasionally, men have breathed the air issuing from a drain, and have suffered from it most unequivocally. Dr Clouston* records a good case of this kind. After inhaling the gas, the man felt ill, languid, and had no appetite for four days, and was then attacked with a violent colic, vomiting, purging, and great prostration.

Dr Herbert Barker† has attempted to submit this question to experiment by conducting the air of a cesspool into a box where animals were confined. The analysis of the air showed the presence of carbonic acid, sulphuretted hydrogen, and ammonium sulphide. The reaction of the gas was usually neutral, sometimes alkaline. The gas was sometimes offensive, so that organic vapours were probably present; but no analysis appears to have been made on this point. Three dogs and a mouse were experimented on; the latter was let down over the cesspool, and died on the fifth day. The three dogs were confined in the box; they all suffered from vomiting, purging, and a febrile condition, which, Dr Barker says, "resembled the milder forms of continued fever common to the dirty and ill-ventilated homes of the lower classes of the community." But the effects required some time, and much gas for their production. Dr Barker attributes the results, not to the organic matter, but to the mixture of the three gases, carbonic acid, sulphuretted hydrogen, and sulphide of ammonium, and especially to the latter two.

With respect to the special production of typhoid fever among sewer-men, Parent-Duchâtelet refers only to three cases of cerebral and bilious affection, which may have been typhoid; there is, however, no certainty. He does not state whether any of the men had been protected by previous attacks, and the large number of men who had been but a short time in the sewers would render this inquiry of little value.

Dr Guy, from an inquiry in London,‡ believed that these men were not more subject to fevers than other workmen, but, as Dr Murchison has pointed out,§ Guy's conclusions are questionable, especially from the distinction of typhus and typhoid fevers not being drawn, and from the mixing up scavengers and dust-men with sewer-men.

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* Medical Times and Gazette, June 1865.
† On Malaria and Miasmata, by T. H. Barker, M.D., 1863, p. 176, *et seq.*
‡ Journal of the Statistical Society, 1848, vol. xi.
§ On Fevers, p. 453.

Murchison and Peacock have both observed sewer-men to be more subject to those diseases. Murchison thinks that constant exposure to sewage air gives immunity, but possibly previous attacks (which are not necessarily severe) may often give protection.

Nightmen, and the collectors and sorters of dust, do not appear, according to Dr Guy, to be subject to any special disease or ill-health.

(*e*.) *Effect of Sewer Air on the General Population.*—The effect of sewer air on the general population is another question. In many towns there is a constant escape of sewage air into the houses; the drains open at the basement are insufficiently trapped, and currents of air force the gas into the house, or the artificial warming of the house continually draws up the air from the sewers. In London, Dr Sanderson has shown, by his ingenious manometer, that the tension of the air in the sewers is always greater than that of the house air, and, consequently, that there is a constant danger of sewer air entering our dwellings.

That the breathing such an atmosphere has an immense effect on health is a matter of such daily observation that, I presume, it will not be denied. Every one must have seen instances in which headache, sickness, diarrhœa, general malaise, and, after a certain time, great depression of health, with more or less anæmia, were produced.* In some cases I have known decided febrile attacks lasting three or four days, and attended with great headache and anorexia. In some cases, houses into which there has been a continued escape of sewer air have been so notoriously unhealthy, that no persons would live in them, and this has not been only from the prevalence of fever, but from other diseases. Dr Marston, R.A., in his excellent paper on the Fever of Malta,† tells us that when typhoid fever broke out at the Fort of Lascaris, from the opening of a drain, other affections were simultaneously developed, viz., "diarrhœa, dysentery, slight pyrexial disorders, and diseases of the primary assimilative organs." A close examination and analysis of the affections produced by the inhalation of sewer air, would probably much enlarge this list; and the class of affections resulting from this cause, to which it may be difficult to assign a nosological name, will be found, I believe, to be essentially connected with derangement of the digestive rather than with the pulmonary system.

Is typhoid fever produced by the emanations arising from fæcal decomposition?

This great question is almost too large for the limits of this book, and yet it is too important to be briefly dismissed. The main facts which we may, I believe, legitimately draw from the long discussion which has taken place are these:—

1. There are several cases on record in which typhoid fever has constantly prevailed in houses exposed to sewage emanations, either from bad sewers, or from want of them, and in which proper sewerage has completely removed the fever.‡

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* It is impossible to quote the numerous instances which have been recorded. Many are given in the Health of Towns Reports. (See Evidence of Rigby, vol. i. p. 121; Aldis, vol. i. p. 115.)

† Army Medical Report for 1861, p. 486.

‡ Whoever will take the trouble to read the Health of Towns Reports and Evidence, Mr Simon's Reports, Dr Letheby's Reports, Dr Acland's Report on Fevers in Agricultural Districts, and the Reports of the Medical Officer to the Privy Council, will find abundant evidence in support of this assertion. Many provincial towns in England could give similar evidence, as Norwich. (See Dr Richardson's Report, Medical Times and Gazette, Jan. 1864.) The case of Calstock, in Devonshire, may be also noted. It used to be always liable to outbreak of typhoid fever, but after the drainage of the place the fever disappeared. (Bristowe in Trans. of Epid. Soc. vol. i. p. 396.)

2. There are several cases on record* (Croydon, Peckham, Westminster, Fleet Lane, Hammersmith, Malta) in which the opening of a drain (in some cases an old one) has given rise to decided typhoid fever, as well as to an extremely severe and rapidly fatal disease (probably severe typhoid), in which coma is a marked symptom. (Murchison on Fevers, p. 438.) And there are other cases (Windsor) in which typhoid fever was manifestly caused by ill-ventilated and ill-contrived sewers permitting a large reflux of air into the houses. A case of this kind in a training school was related to me by a friend. The house is on an eminence, and the sewers led down at once to a large tank below; the pipes got out of order in certain parts of the house, and in those parts typhoid fever appeared. It was worthy of note, that in this case the smell of the sewage air was so slight, that at first the outbreak was believed to be independent of the drains.

3. Whenever statistics are accurately carried on, the prevalence of typhoid fever is always found to be in a close relation to the imperfect manner in which sewage matters are removed. The army statistics of home and foreign stations give us excellent examples of this, and year by year, as diagnosis is becoming more certain, this fact is coming out more and more clearly.

These three classes of facts are so undoubted, and so numerous, as to show that the connection between typhoid fever and fæcal emanations is too intimate to be accidental. But,

4. There are cases on record in which fæcal accumulation and decomposition has been going on about habitations for years without producing fever. Certainly many of these cases are in small villages and isolated houses, where there are currents of air to carry off the effluvia, and not in close towns and alleys. The difference may, then, be merely one of ease of oxidation and dispersion. In some of these instances again, and especially in the case of foreign towns, fever may really greatly prevail, though casual observers do not recognise it; it may affect the children under the form of the so-called infantile remittent fever, and in this way preserve them from subsequent attacks. Strangers suffer in such towns, but apparently not the inhabitants. A closer examination may, perhaps, detect the reason of this to be the protective influence of prior attacks.† In other cases, again, the fever really prevails among adults, but is not recognised.‡ How constantly it used to be said that typhoid fever prevailed in neither the East nor the West Indies. It really prevails in both, and doubtless has always been present, but was confounded with other diseases. Still, will these explanations account for all cases? The cases of two villages are known to me in which no typhoid fever had ever been known; the drainage arrangements were, as usual in our English villages, very bad. At length typhoid fever commenced to prevail, and spread completely through the villages, attacking old and young, so completely unprotected were all the inhabitants. Importation could not be traced in either

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* For many instances, see Murchison on Fevers, p. 436, *et seq.* The Hammersmith case is mentioned by Marston (Army Medical Report for 1861, p. 486). The case at Malta is one mentioned by Babington (British Medical Journal, May 3, 1862). I have been informed of a similar case; and it was also affirmed that the evacuations of some patients with typhoid fever had been received two years before into the drain. Riecke (Der Kriegs und Frieden-Typhus, 1850, p. 51) has collected many cases; so also Giell (Die Ursachen des Ent. Typh. in Munich, 1862), and, in fact, the connection of typhoid fever with sewage exhalations seems to rest on as large a body of evidence as the best established medical opinions.

† There seems little doubt that one attack of typhoid usually protects from another. Is this owing to the destruction of Peyer's patches; and is the fever really caused by the absorption of the products of these glands, when disintegrating from the effects of a poison locally applied to them? The transmission of the disease by water gives some countenance to this.

‡ This is the case still in London; there is reason to think that many cases of typhoid occur in private practice which are not diagnosed.

case, but it is not certain it did not occur. Now here, as in the cases of Calstock and Over Darwen, recorded by Bristow and Greenhow,* either the accumulation of, and emanations from, sewage must reach a certain point, or there must be some special superadded meteorological conditions, such as excessive heat, drought, &c., or there must be entrance of a fresh agent.

5. There are cases in which, in such local outbreaks, no introduction of a fresh agent can be traced. But then it is notoriously difficult to prove a negative, and these specific poisons pass from place to place in such secret ways that it is almost impossible to trace them. A great number of negative instances must be brought together before much reliance can be placed on this argument.

6. There are cases on record (the outbreak at Steyning, recorded by Whitley,† is one of the best) in which all the conditions of typhoid fever from accumulated sewage are present for years, and yet no fever is caused. Then, a patient arrives from a distance with typhoid fever, and the disease spreads more or less through the village, and, spreading evidently from this case, is disseminated as evidently by the fæcal emanations. Now, such cases as these support very strongly Dr William Budd's view, that the specific poison must be introduced, and that it is conveyed in the stools, and, as a matter of course, propagated through the sewers, if these exist.

7. There are cases in which typhoid fever occurs when no exposure to sewage emanations can be traced. But these instances are always isolated; and it is well known that, in such cases, it is not to be expected we shall always be able to point out the exact place and time of exposure. A man may be exposed to a vitiated atmosphere without even knowing it himself, and even the time and place of exposure to the most undoubted contagions (as small-pox) cannot always be traced.

The general conclusion seems to me to be this. The view which meets best all the facts is that sewage air, *per se*, does not produce the specific lesion of Peyer's patches, which is the anatomical sign of typhoid fever, but that sewers afford the channels of propagation when the specific poison of typhoid, derived from the stools, finds its way into them. At the same time, it must be confessed that this conclusion is not based on such complete evidence as should alone content us, and that the spontaneous origin of true typhoid fever from simple sewage matter is neither completely disproved, nor is evidence wanting which seems to indicate such an origin. That the effluvia from the typhoid stools will produce typhoid fever seems to be certain, and a good case is given by Riecke. The evacuations of a typhoid patient were placed in an outhouse, the upper room of which had an unceiled floor. Two men who had no intercourse whatever with the patient, and never entered the house, but who slept in the upper room, were attacked, and at the same time.

With regard to the production of diarrhœa from fæcal emanations, it would seem that the autumnal diarrhœa of this country is intimately connected with temperature,‡ and usually commences when the thermometer is persistently above 60°, and when there is, at the time, a scarcity of rain-fall. It is worst in the badly sewered districts, and is least in well-drained districts, and in wet years. It has been checked in London by a heavy fall of rain. All those points seem to connect it with fæcal emanations reaching a certain rapidity of evolution in consequence of high temperature, deficient rain, and

* Fourth Report of the Medical Officer to the Privy Council.
† Ibid. p. 43.
‡ Ransome and Vernon, "Influence of Atmosph. Changes on Dis." p. 3.

perhaps relative dryness of the atmosphere. At the same time, there is a connection between this disease and impure water. It may own a double origin, and in a dry season both causes may be in operation.

To sum up, the diseases produced by fæcal emanations on the general population seem to be, diarrhœa, bilious disorders, often with febrile symptoms; dyspepsia, general malaise, and anæmia; all these being affections of digestion or sanguification; typhoid fever is also intimately connected with sewage emanations, either being their direct result, or, more probably, being caused by specific products mixed with the sewage.

In addition, sewer air aggravates most decidedly the severity of all the exanthemata, erysipelas, hospital gangrene, and puerperal fever (Rigby), and probably has an injurious effect in all other cases.

(*f.*) *Emanations from Fæcal Matter thrown on the Ground.*—Owing, doubtless, to the rapid movement of the air, there is no doubt that the excreta of men and animals thrown on the ground and exposed to the open air are less hurtful than sewer air, and probably in proportion to the dilution.

When there are accumulations in close courts, small back-yards, &c., the same effects are produced as by sewer air, and many instances are recorded in the Health of Towns Reports. When fæcal matters are used for manure, and are therefore speedily mixed with earth, they seldom produce bad effects. Owing, doubtless, to the great deodorising absorbing powers of earth, effluvia soon cease to be given off. An instance is, however, on record,* in which two cases of typhoid were supposed to arise from the manuring of an adjacent field. Dr Clouston† has also shown by evidence, which seems very strong, that dysentery was produced in an asylum by the exhalations from sewage, which was spread over the ground (a stiff brick clay subsoil) about 300 yards from the asylum. The case seems a very convincing one, as the possibility of the action of other causes (impure water, bad food, &c.) was excluded. This is a point on which more evidence is desirable. It is stated in some works that disease is frequently produced by the manuring of the ground, but I have been able to find no satisfactory evidence. It has been said that if the sewage matter can be applied while perfectly fresh to the ground, no harm results; but if decomposition has fully set in, it is not so completely deodorised by the ground. (See chapter on Sewage.)

(*g.*) *Emanations from Streams polluted by Fæcal Matter.*—The evidence on this point is contradictory. Parent-Duchâtelet, in 1822,‡ investigated the effect produced on the health of the inhabitants of the Faubourg St Marceau, in Paris, by the almost insupportable effluvia arising from the Rivière de Bièvre, which received a large portion of the sewage of the quarter. He asserts that the health was not at all damaged, though he admits that there is truth in the old tradition at the Hotel Dieu, that the cases from St Marceau were more severe than from any other place.

Dr M'William found that the emanations from the Thames in 1859–60 had no deleterious effect on the health of the Custom-House men employed on the river. The amount of diarrhœa was even below the average.

Mr Rawlinson states (Report of Committee on Sewage, 1864, p. 174, Question 3997) that a careful house to house visitation had been made in some of the worst districts of Lancashire (in Manchester, on the banks of the Medlock, for instance) without finding any great excess of disease.

On the other hand, in the reports of Sir H. De la Beche and Dr Lyon

* Whitby, Med. Times and Gazette, Jan. 1862.
† Medical Times and Gazette, June 1865.
‡ Hygiène Publique. t. i. p. 98.

Playfair,* is some strong evidence that the general health of the people suffered from the emanations of the putrid streams of the Frome, and the tributaries of the Irk and Medlock; that they were pale, in many cases dyspeptic; that fevers (typhoid) prevailed on the banks is asserted by some observers, but rather doubted by others; but none seem to have any doubt that the fevers, when they occurred, were much worse. Cholera in Manchester was severe along the banks of some of these streams, but that might have been from the water being drunk. In 1858 also, Dr Ord† observed that a large number of the men employed on the Thames were affected by the effluvia; the symptoms being languor and depression, followed by nausea and headache, aching of the eyeballs, and redness and swelling of the throat. Diarrhœa was rare. In 1859 these symptoms were not observed, though the state of the river was worse. Were they then really caused by the effluvia in 1858?

It is very likely that the discrepancy of evidence may arise from the amount of water which dilutes the fæcal matter being much greater in some cases than others. In the case of the Thames, the dilution was after all very great, and this was the case, in part at any rate, in the Bièvre, as the stream was in some places 6 and 7 feet deep. The evaporation from such a body of water, however offensive it may be, must be a very different thing from the effluvia coming off from the masses of organic matter laid bare by the almost complete drying up of streams into which quantities of fæcal matter are poured.

(*h.*) *Effect of Manure Manufactories.*—The manure manufactories at present existing in this country do not appear to produce any bad effects. They are generally at some little distance from towns, and the effluvia are soon diluted. The Secretary of the Hyde Manure Company informs me that while the works were in operation no bad effects were produced. But if situated in towns they are nuisances, and may be hurtful. In 1847 evidence was given to show that a manure manufactory situated in Spitalfields, and about 100 feet from the workhouse, caused bad diarrhœa whenever the wind blew in that direction, and 12 cases of "spontaneous gangrene"(!) which had appeared among children were attributed to it. The cases of disease in the workhouse infirmary also acquired, it was said, a malignant and intractable character.‡ In France the workmen engaged in the making of "Poudrette" do not in any way suffer, except from slight ophthalmia.§ Parent-Duchâtelet‖ (on very slight evidence indeed) thought the emanations were even beneficial in some diseases, and Tardieu seems inclined to support this opinion. The Secretary of the Hyde Manure Company informs me that some of the men appeared actually better in health. When the poudrette is decomposing, and large quantities are brought into small spaces, as on board ship, serious consequences may certainly result. Parent-Duchâtelet records two cases of out-

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* Second Report of the Health of Towns Commission, pp. 261 and 347. Lyon Playfair says, "The medical men in Manchester whom I have consulted are unanimously of opinion that the emanations from the putrid streams which wind their way sluggishly through the town are a cause of disease and mortality." On the other hand, Whitehead (Rate of Mortality in Manchester, 3d edit. 1864, p. 50) denies that typhus (typhoid?) is more prevalent near the banks of these streams, and also denies (p. 52) that health is injuriously affected. Mr Rawlinson also (Report of Sewage Committee, 1864, p. 174, Question 3997) states that no great excess of disease from exhalations was found to exist on the banks of the Medlock. So also the state of the Clyde, which is at present very bad, produces no effect whatever on health. (See Glasgow Medical Journal for Nov. 1868.)

† Trans. Social Science Association, 1859, p. 571.

‡ "Medical Gazette," December 1847.

§ Parent-Duchâtelet; Patissier. See also Tardieu, "Dict. d'Hygiène," t. iv. p. 453. Tardieu, in 1862, writes,—"We do not hesitate to affirm that the exhalations from these manufactories (voiries) exercise no injurious action either on man or vegetation." But it must be remembered that these places are excellently conducted; ventilation is good, and the fæcal matter is soon subjected to processes which prevent its decomposition.

‖ Hyg. Publique, t. ii. p. 276.

breaks on board ships carrying poudrette which fermented on the voyage; one vessel, the Arthur, lost half her crew (number not known), and the rest were in a state of deplorable health; the men who unloaded the cargo were also affected. The symptoms are not recorded, but, in a smaller vessel, where all on board (5) were similarly affected, the disease put on the appearance of "an adynamic fever." There was intense pain of the head and of all the limbs, vomiting, great prostration, and in two cases great diarrhœa. These symptoms are very similar to those already mentioned as produced in the children at Clapham by the opening of a privy.

(*i.*) *The Air of Graveyards.*—There is some evidence that the disturbance of even ancient places of sepulture may give rise to disease. Vicq d'Azyr refers to an epidemic in Auvergne caused by the opening of an old cemetery; the removal of the old burial-place of a convent in Paris produced illness in the inhabitants of the adjoining houses.* In India, the cantonment at Sukkur was placed on an ancient Mussulman burial ground, and the station was most unhealthy,† especially from fevers.

The effect of effluvia from comparatively recent putrefying human bodies has been observed by many writers. Rammazzini‡ states that sextons entering places where there are putrefying corpses are subject to malignant fevers, asphyxia, and suffocative catarrhs; and Fourcroy remarks that there are a thousand instances of the pernicious effects of cadaveric exhalations; and Tardieu§ has collected a very considerable number of cases, not only of asphyxia, but of several febrile affections produced by exhumations and disturbance of bodies. Mr Chadwick,‖ and the General Board of Health,¶ have also summed up the recent evidence, which shows that in churchyards thickly crowded with dead, vapours are given off (see page 94), which, if not productive of any specific disease, yet increase the amount both of sickness and mortality. In some instances, this may be from contamination of the drinking water; but in other cases, as in the houses bordering the old city graveyards, where the water was supplied by public companies, the air also must have been in fault. In the houses which closely bordered the old city yards, which were crowded with bodies, cholera was very fatal in 1849,** and I was informed by some practitioners that no cases recovered. I was also informed that all other diseases in these localities assumed a very violent and unfavourable type.

(*k.*) *Effluvia from Decomposing Animals.*—On this point there is some discrepancy of evidence.

In 1810, Deyeux, Parmentier, and Pariset, gave evidence to show that the workmen in knackeries are in no way injured. Parent-Duchâtelet, from his examination of the health of the men employed at the knackery and slaughter-house at Montfauçon, came also to the conclusion that their health was not affected. It should be mentioned that this knackery is remarkably well placed for ventilation, and is excellently conducted; putrid remains, in the proper sense of the word, do not now exist in any knackery in or near Paris; the workmen are well paid and well fed, and are therefore prepared to bear the effect of any injurious effluvia. It has been stated, however, that in the Hôtel Dieu, the patients used to suffer when the wind loaded with effluvia blew from Montfauçon (Henry Bennet). Tardieu, from a late re-examination of the question, confirms Parent's conclusions,†† except as regards glanders

* Tardieu, "Dict. d'Hygiène," i. p. 517.
† Norman Chevers, European Soldiers in India, p. 404.
‡ Maladies des Artizans, p. 71.
§ Dict. d'Hygiène, 1862, t. iii. p. 463, *et seq.*
‖ Report on Interments in Towns.
¶ Report on Extramural Sepulture, 1850.
** S. Smith, and Sutherland's Report on Extramural Interment, p. 12. See also Sutherland's Report on Cholera, 1850, p. 27.
†† Dict. d'Hygiène, t. iv. p. 468.

and malignant pustule, touching which Parent-Duchâtelet's evidence was as usual negative. Tardieu (t. iv. p. 468), however, states that many examples occur in the French knackeries of the transmission of these diseases, though glanders and farcy are less frequently caught in knackeries than in stables. No analysis has yet been made of the air of knackeries.

Parent-Duchâtelet* is often also quoted, as having proved that the exposure of the remains of 4000 horses, killed in the battle of Paris in 1814, produced no bad effects. These horses were killed on the 30th March, and were burnt on the 10th and 12th April. They gave out "une odeur infecte," which produced no bad results on those who collected the bodies. Parent-Duchâtelet inquired particularly whether typhus was produced by the effluvium, and proved that it was not; a conclusion conformable to our present doctrine. He did not, however, do more than examine the registers of deaths for the three years before, during, and after the battle, and found no evidence of increased mortality. The utmost this observation shows is, that no typhus was produced; and that the amount of decomposition, caused by eleven days of hot weather, did not affect those concerned in collecting and burning the bodies.

On the other hand, the experience of many campaigns, where soldiers have been exposed to the products of an advanced putrefaction of horses, shows that there is a decided influence on health. Pringle especially noticed this; and in many subsequent campaigns this condition has been one of the causes of insalubrity. Diarrhœa and dysentery are the principal diseases; but all affections are increased in severity. At the siege of Sebastopol, where, in the French camp, a great number of bodies of horses lay putrefying on the ground, Reynal† describes the effect as most disastrous, and even conjectures that the spread of typhus was connected with this condition.

(*l.*) *Air of Brickfields and Cement Works.*—The peculiar smell of brickfields cannot be owing to carbonic acid, carbonic oxide, or to hydrosulphuric acid, or sulphurous acid (the gases evolved from the kilns); but its exact cause, I believe, is not known. The air, at its exit from the chimney of furnaces and kilns, is rapidly fatal; but so rapid is its ascension, dilution, and diffusion, that at a little distance it is respirable. I am not aware that, in any of the actions against the owners of brickfields, anything more than a nuisance has been established. The smoke and gases from cement works, however, destroy neighbouring vegetation. The smell can be perceived for several hundred yards. In the north of France, it is ordered that no kilns shall be within 50 mètres ($54\frac{1}{2}$ yards) of a public road; and the kilns are lighted only at night.

(*m.*) *Air of Tallow-makers, Bone-burners, &c.*—In many trades of this kind large quantities of very disagreeable animal vapours are produced, which spread for a long distance, and are most disagreeable. Although a nuisance, it is difficult to bring forward positive evidence of insalubrity. But the odour is so bad, that in France rules are in force to oblige the vapours to be condensed or consumed,‡ and if in the process any water is contaminated with fatty acids, it is neutralised with lime. M. Foucon has figured an apparatus which completely burns the animal vapours.§

(*n.*) *Air of Marshes.*—It seems scarcely necessary to allude to this point, except to notice that, in addition to paroxysmal fevers, it has been supposed that serous diarrhœa (a sort of dysenteria incruenta) and true bloody dysentery are produced by malaria. Also that there is perhaps some connection with malaria and liver abscess (?). In addition to marked diseases, the breathing of marsh air produces an imperfect condition of nutrition, in which

* Dict. Hygiène, t. i. p. 47.
† Vernois, Hygiène Industrielle, t. ii. p. 60.
‡ Tardieu, Dict. d'Hygiène, t. xi. p. 221.
§ Pappenheim's Beit. der Sanitat. Pol. Heft. ii.

enlarged spleen plays a prominent part, and the mean duration of life is shortened.

(o.) *Unknown conditions of the Atmosphere.*—Occasionally, outbreaks of disease occur from impurities of the atmosphere, the nature of which is not known, though the causes giving rise to them may be obvious. Dr Majer* records a case of a school at Ulma, of sixty or seventy boys, where the greater number were suddenly affected, on a warm day in May, with similar symptoms—giddiness, headache, nausea, shivering, trembling of the limbs, sometimes fainting. The attack occurred again the next day, and a common cause was certain. The room was enclosed by walls, in a narrow space, where the snow had lain all the winter; the wall was covered with fungous vegetation, and with salts from the mortar. From the sudden entrance of warm weather, fermentation had set in, and a strong marshy smell was produced; the substances of whatever kind generated in this way accumulated in the narrow, ill-ventilated space. Removal to a healthier locality at once cured the disease.

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* Canstatt's Jahresb. 1862, vol. ii. p. 32.

Since the chapter on Air was in type, a work by Dr Trautman (Die Zersetzungsgase als Ursache zur Weiterverbreitung der Cholera, 1869) has reached me. Dr Trautman has examined the molecules floating in the air, and finds, as others have done before him, innumerable little molecules and cells in the air, and in the water condensed from the air. They are, he finds, far more numerous in badly than in well-ventilated rooms, and it is to them he ascribes the peculiar smell of a badly ventilated room. They increase by the molecules becoming cells when they meet with fluid in the air, and multiply at an extremely rapid rate by division; they are the same bodies as those described by Lemaire, and are noticed by others as Bacteria, Vibriones, and are classed under the heading Schizomycetæ. Trautman names them "decomposition-cells" (zersetzungszellen). The important point, however, which he believes he has proved, is the marked effect produced on their growth by certain gases, particularly by sulphuretted hydrogen, in which they increase incredibly. On the other hand, their increase was greatly checked, though not altogether arrested, by carbolic acid vapour. But the vapour arising from a mixture of coal-tar oil and lime was still more efficacious. (See chapter on DISINFECTION.)

The existence of small round bodies in the air is tolerably certain, but Trautman's statement as to their growth by division and the action of gases upon them require verification.

CHAPTER III.

VENTILATION.

The term ventilation is not always used in the same sense. By some it is applied to the dilution and removal of all impurities which can collect in the air of inhabited rooms. The most common causes of such impurities are the respiration and cutaneous transpiration of men, the products of combustion of lights, the effluvia of simple uncleanliness of rooms or persons, the products of the solid or fluid excreta retained in the room, or in hospital discharges from the body or from dressings. In addition, there may be special conditions which allow impure air to flow into a room, as from the basement of a house, or from impurities outside a house.

It will be desirable, however, to restrict the term ventilation to the removal, by a stream of pure air, of the pulmonary and cutaneous exhalations of men, and of the products of combustion of lights in ordinary dwellings, to which must be added, in hospitals, the additional effluvia which proceed from the persons and discharges of the sick. All other causes of impurity of air ought to be excluded by cleanliness, proper removal of solid and fluid excreta, and attention to the conditions surrounding dwellings.

Army Regulations on Ventilation.

The Inspector-General or Deputy-Inspector, or Sanitary Officer or Regimental Surgeon, is directed by the Hospital Regulations to see that the ventilation of barracks, guard-rooms, day-rooms, schools, reading-rooms, cells, and hospitals is good, and that the number of men in any room does not exceed the regulation number.

The number of men placed in a barrack-room or hospital-ward is to depend on the cubic space.

In permanent barracks a man is allowed . .	600	cubic feet.*
In wooden huts, ...	400	,,
In hospital wards at home, ...	1200	,,
,, ,, in the tropics, . . .	1500†	,,
In wooden hospitals at home, ...	600	,,

* In the metropolitan lodging-houses, 30 superficial and 240 cubic feet are allowed; in the section-houses of the metropolitan police 50 feet superficial and 450 cubic feet are given. The Poor-law Board allows 300 cubic feet for every healthy person in dormitories, and from 850 cubic feet and upwards, according to circumstances, as far as 1200 cubic feet for every sick person. In Dublin an allowance of 300 cubic feet is required in the registered lodging-houses. —(From an excellent pamphlet entitled "Essentials of a Healthy Dwelling," p. 12.) In the Prussian army the allowance is 495 cubic feet (Prussian measurement, which is nearly the same as English), the superficial space being 42--45 square feet; in the old Hanoverian army the cubic space was 700 to 800 cubic feet (Prussian).

† See Chapter on India for the recommendations on this point.

The number of men in each room is ordered to be painted on the door. (Part. iv. sec. iii.)

Before temporary hospitals are organised, the sanitary or other medical officer is to consider and report on the ventilation as well as other things.

The surgeon or medical officer in charge of a regiment is directed to visit "at frequent intervals" all barracks, quarters, hospitals, cells, married soldiers' quarters, to note their general sanitary condition, including ventilation. He is also to examine latrines, stables, &c.

On field service and on transport ships the same duties are enjoined.

The most constant attention is therefore ordered to be paid to this subject.

With the exception of ordering a certain cubic space, the Medical Regulations do not give any specific rules as to the rate of change of air, but the Report of the Barrack Commissioners (1861) orders that arrangements be made to supply at least 1200 cubic feet per head per hour; or, in other words, that the 600 cubic feet of air shall be changed twice in the hour.

In the Queen's Regulations for the Army, the ventilation of cells, barracks, and transport ships is also ordered.

The regulations thus require the medical officer to be able to report on the sufficiency or otherwise of ventilation; or, in other words, on the rate of movement, and on the purity of the air.

How the requisite amount of pure air can be given is an engineering problem, and forms the subject of the chapter on VENTILATION.

Division of the Subject.

The subject of ventilation may be conveniently considered under the following heads:—

1. The quantity of fresh air required for the purposes defined above.
2. The mode in which this quantity may be supplied.
3. The method of examining whether ventilation is sufficient; in other words, whether the air of inhabited rooms is properly pure. This will form the subject of a separate chapter.

SECTION I.

QUANTITY OF AIR REQUIRED.

1. *Quantity required to remove the respiratory impurities caused by healthy persons.*

The impurities added to the air by respiration have been already enumerated (p. 89).

The carbonic acid which an adult man adds, to the extent of about $\frac{6}{10}$ths of a cubic foot in an hour, is not within certain limits an important impurity, but as it is practically in a constant ratio * with the more important organic matter of respiration; and, as it is readily determined, it is taken as a convenient index to the amount of the other impurities.

Taking the carbonic acid as the measure of the impurity of the air vitiated by respiration (and by respiration alone), we have to ask, What is to be considered the standard of purity of air in dwelling-rooms? We cannot demand

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* I say it is practically in a constant ratio, because it is so in perhaps 99 cases out of 100 though there may be exceptional cases when the organic matter may be in excess.

that the air of an inhabited room shall be absolutely as pure as the outside air; for nothing short of breathing in the open air can ensure perfect purity at every respiration.* In every dwelling-room there will be some impurity of air.

The practicable limit of purity will depend on the cost which men are willing to pay for it. If cost is disregarded, an immense volume of air can be supplied by mechanical contrivances, but there are comparatively few cases in which this could be allowed.

Without, however, attempting too much, it may be fairly assumed that the quantity of air supplied to every inhabited room should be great enough to remove all sensible impurity, so that a person coming from the external air should perceive no trace of odour, or difference between the room and the outside air in point of freshness. Taking the carbonic acid as the index of impurity, it appears, from experiments made by Dr de Chaumont and myself, that the organic impurity of the air is not perceptible to the senses until the carbonic acid (*i.e.*, the initial and the respiratory carbonic acid) rises to the ratio of ·6 per 1000 volumes. Occasionally air may seem pure to the senses when the carbonic acid is ·7 or even ·8 per 1000 volumes, but the usual rule seems to me that when it exceeds ·6, the air commences to become perceptibly impure. When the carbonic acid reaches ·9 or 1· per 1000 volumes, the air is what is called close and fusty; above this it becomes disagreeable.† In order to perceive the smell of the organic matter, the room should be entered from the fresh outside air, as after the observer has been a few minutes in the room the odour becomes imperceptible.

I would propose, then, to adopt the amount of ·6 per 1000 volumes of total carbonic acid (initial and respiratory) as the limit of impurity. I admit that I am not able to show by direct evidence that impurity, indicated by ·7 or ·8, or even 1 volume of carbonic acid per 1000, and organic impurities in proportion, is injurious to health. We possess no means of testing the effects of such small quantities. Such a standard must be adopted, first, on the general evidence that large aerial impurities are decidedly hurtful, and that smaller amounts may be presumed to be so in proportion, although we cannot measure the action; and secondly, on the fact that we have an obvious and simple measure in the effect produced on the senses, which gives us a practical line of demarcation we could not otherwise obtain.

Adopting then the standard of ·6 volumes of carbonic acid (CO_2) per 1000 volumes of air as the measure of the permissible maximum of impurity, the next point is the quantity of pure external air which should pass through the air of a room vitiated by respiration per head per hour, in order to keep the carbonic acid at the ratio of ·6 per 1000 volumes. The following table gives the answer to this question, under different conditions of cubic space.

* Thus the carbonic acid in the air being taken at ·04 per cent., and the carbonic acid of respiration being placed at ·6 cubic feet in an hour, a man placed in a room of 1000 cubic feet of air must receive no less than 1,000,000 cubic feet of outside air in an hour to reduce the carbonic acid to the standard (nearly ·0401 per cent.) of the fresh air.—*On Ventilation and Cubic Space.* By Dr de Chaumont, Assistant Professor of Hygiene, Army Medical School. Edinburgh Med. Jour. May 1867.

† Dr Michael Foster, in his excellent article on Respiration (Watt's Dict. on Chemistry, vol. v. p. 97), has fixed a higher limit, viz., when the carbonic acid from respiration reaches ·08 per cent.; this, with the initial carbonic acid, would be 1·2 per 1000 volumes; the air is, however, very offensive to the senses with this amount.

TABLE *to show the degree of Contamination of the Air (in terms of carbonic acid) by Respiration, and the amount of air necessary to dilute to a given standard of ·6 per 1000 volumes of air, of which ·4 is the carb: acid naturally existing, and ·2 is from respiration. In the table a deduction is made of the initial ·4 volumes of carbonic acid per 1000, for the sake of clearness.*

Amount of cubic space (= breathing space) for one man in cubic feet.	Percentage of carbonic acid from respiration at the end of one hour, if there has been no change of air.	Amount of air necessary to dilute to standard of ·2, or including the initial carbonic acid of ·6 per 1000 volumes, during the first hour.	Amount necessary to dilute to the given standard every hour after the first.
100	·6	2900	3000
200	·3	2800	3000
300	·2	2700	3000
400	·15	2600	3000
500	·12	2500	3000
600	·1	2400	3000
700	·085	2300	3000
800	·075	2200	3000
900	·066	2100	3000
1000	·060	2000	3000

As already stated, for the sake of simplicity the carbonic acid naturally in the air has been disregarded, but, of course, there would be actually in the air ·04 volumes per cent. more from this source. Thus in the room of 100 cubic feet there would be at the end of an hour (·04 + ·6) ·64 volumes, and in the room of 200 cubic feet there would be ·34 volumes.

The above table is calculated by the following formula of Dr de Chaumont's :—*

Let R be the ratio of CO_2 naturally in the air (viz. ·04 per cent.);
r' be the ratio of vitiation by respiration, taken as ·6 cubic feet in one hour diffused uniformly in the air space;
r be the ratio to which it is desired r' should be reduced;
c – be the capacity in cubic feet of the air space;
d – be the delivery of fresh air in cubic feet;
v – be the entire volume of the air, viz., $c + d$;

$$\frac{r' - R}{r - R} \times c = v \text{ and } v - c = d;$$

or, in other words, deduct from both ratios of vitiation (r' and r) the initial

* Lancet, Sept. 1866, and Edin. Med. Journal, May 1867. These papers can be referred to for several useful formulæ. I would also refer to the Blue-book of the Committee on the Cubic Space of Metropolitan Workhouses (1867), in which will be found several papers, especially one by Professor Donkin, in which this subject is mathematically treated. Professor Donkin gives a formula, which is the same as one by Dr de Chaumont, and which may be useful. I have used Dr de Chaumont's symbols. To determine the delivery required to retain an occupied space at a given rate of purity. Let n be the number of men; e the carbonic acid expired by one man in an hour (say ·6 cubic feet); h the number of hours the room is occupied; c the cubic space; r the desired ratio of purity per cubic foot, and r'' the ratio at commencement of the supply of air, and R the ratio per cubic foot in the pure air; $\frac{neh + c(r'' - r)}{r - R}$ = delivery of air in the time for the specified number of men; or the formula may be simplified as follows :— $\frac{e}{r - R}$ = delivery of air per head per hour in cubic feet; and from this formula we can also find the actual movement of air which has taken place in an air space by substituting for r the *observed* ratio of impurity per foot.

carbonic acid of the fresh air, divide the ratio of the vitiated air, viz. r', by the ratio to which it is to be reduced, viz. r, and multiply by the cubic space, using the multiplier as a round number. In the table already given, as the standard of practicable purity is taken as ·02 per cent. of CO_2 from respiration, and this is $\frac{1}{30}$ of ·6 (the percentage, that is, if vitiation from respiration in the room with 100 cubic feet), the multiplier is 30; in the room with 200 cubic feet ·02 is $\frac{1}{15}$th of ·3 (the percentage of vitiation), and the multiplier is 15, and so on.

If the standard of practicable purity, viz., ·6 of carbonic acid per 1000 volumes (of which ·2 is derived from respiration) is considered too high, and if ·7, ·8, or ·9 be taken, the amount of air required per head per hour will be 2000, 1500, and 1200 cubic feet respectively. If the emission of carbonic acid is taken, not at ·6 cubic feet per hour, but as something less, as in the case of women and children, a less amount of air would suffice, and can be calculated out at once from the formula. The amount of air actually entering a room inhabited by men may be ascertained with considerable precision by determining the amount of carbonic acid, provided there be no other source of vitiation of the air than respiration. If the total carbonic acid amount, for example, at the end of an hour, to ·9 per 1000 volumes, of which ·5 is from respiration, the total amount of fresh air already in or entering in the hour has been 1200 cubic feet.*

The amount of fresh air thus determined by calculation is in accordance with that determined by actual experiment. I have measured the air passing out of barracks and hospital wards, and found that when 1200 or 1400 cubic feet per head per hour only were given, the carbonic acid reached ·7, ·8, or ·9 per 1000 volumes, and that more than 2000 cubic feet were necessary to keep the air pure to the senses. Dr de Chaumont's analyses† agree closely with this; so also the older experiments by Grassi, in Paris, at Mazas, and the later observations of General Morin, as well as the observations and calculations of others, all fairly agree in this respect.

General Morin,‡ from analysis of all the observations made in Paris, and from experiments of his own, gives the following amounts:—

Amount of fresh air to be supplied per head per hour in temperate climates in the following circumstances:—

In Barracks,	= 30 cubic metres by day— 60 by night.	
	= 1059 cubic feet ,, —2118 ,,	
,, Workshops,	= 60 cubic metres.	
	= 2118 cubic feet.	
,, Prisons,	= Ibid.	
,, Theatres,	= Ibid.	
,, Schools	= 30 cubic metres.	
	= 1059 cubic feet.	
,, Hospitals	= 80 cubic metres day and night.	
	= 2825 cubic feet.	
,,	= 120 cubic metres,	during hours of dressing.
	= 4236 cubic feet,	
,,	= 160 cubic metres,	during epidemics.
	= 5650 cubic feet,	

* In reference to the proposed standard, it is now earnestly to be wished that there should be a general agreement among medical men on the point; and I hope that the reasons already assigned will be considered sufficient to warrant the general adoption of ·06 per cent. of carbonic acid as the standard of permissible maximum impurity.

† Army Medical Department Reports, vols. v., vi., and vii.

‡ Rapport de la Commission sur le Chauffage et la Ventilation des Batimens du Palais de Justice. Paris, 1860. The older observers gave much smaller amounts, but I do not quote them.

Ranke, in his late work on Physiology,* fixes the quantity at 60 cubic metres (2118 cubic feet) as the necessary minimum amount.

In mines which are thought to be well ventilated, not less than 1400 cubic feet are given per head per hour, and if there is much fire-damp, as much as 6000 cubic feet have been supplied.† A horse requires 2460 cubic feet per hour at the least.

Although, in order to give precision to the subject, it is necessary to attempt to define the minimum quantity which is necessary, there is no doubt that it is advantageous to have a much larger amount. Wherever practicable, we should be contented with nothing short of an almost unlimited supply.

2. *On the Quantity of Air required for Lights, if the Air is to be kept Pure by Dilution.*

Air must be also supplied for lights if the products of combustion are allowed to pass into the room. Wolpert has calculated that, for every cubic foot of gas, 1800 cubic feet of air must be introduced to properly dilute the products of combustion; and this is not too much if we remember that a cubic foot of good coal gas produces about 2 cubic feet of carbonic acid, and that sulphuric acid and other substances may be also formed. A common gas burner will burn nearly 3 feet per hour, and will consume 10 or probably 12 cubic feet in an evening (4 hours), and therefore from 18,000 to 21,600 cubic feet of air must be introduced for this purpose alone in the 4 hours, unless the products of combustion are removed by a special channel. The power of illumination being equal, gas does not produce more carbonic acid than candles (Odling), but usually so much more gas is burnt that the air is much more deteriorated; there is also greater heat and more watery vapour. The lighted gas may be made a valuable agent of ventilation; and should always be so. The products should never be allowed to escape into the air of the room.

A ℔ of oil demands, for complete combustion, 138 cubic feet of air; and to keep the air perfectly pure, nearly as much air must be introduced for 1 ℔ of oil as for 10 cubic feet of gas.

In mines, 60 cubic feet per hour are allowed for each light; the lights generally are dim, and the amount of combustion slight; but this seems an extremely small amount.

If gas is not burnt in a room, or in a very small amount, or if only candles or oil lamps are used, it is seldom necessary to take them into account in estimating the amount of air.

3. *On the Quantity required for the Respiration and Dilution of the Emanations of Sick Men.*

With regard to sick men, it is impossible to say what quantity should be given. In some diseases, so much organic substance is thrown off, that scarcely any ventilation is sufficient to remove the odour. At the Hospital Beaujon in Paris, it was shown, as long ago as 1847, that 60 cubic metres

* Grundzüge der Phys., 1868, p. 376.

† It has been stated, from extensive observations, that, in mines, if it is wished to keep up the greatest energies of the men, no less than 100 cubic feet per man per minute (=6000 per hour) must be given; if the quantity is reduced to one-third, or even one-half, there is a serious diminution in the amount of work done by the men. Mr Robert Stephenson even thought that 100 cubic feet per man per minute would not be enough. This amount includes, of course, all the air wanted in the mine for horses, lights, &c.—*Proceedings of the Civil Engineers*, vol. xii. pp. 298 and 308.

(= 2118 cubic feet) per head per hour did not remove all odour from the surgical wards after dressings. Grassi* mentions that a perceptible odour diffused from a case of cancerous ulcer in a ward in the Hôpital Necker at Paris, although the ventilation at the time was 3500 cubic feet per head per hour; but bad odour will perceptibly taint an hospital ward with a greater allowance of air even than this. Dr Sankey found the wards in the London Fever Hospital to be not free from odour when 3720 cubic feet per head per hour were passing in. In the new Hotel Dieu at Paris, it is intended to give at least 100 cubic metres (3500 cubic feet) per head per hour; but it is questionable whether this is sufficient. Dr Sutherland believes that at least 4500 cubic feet per head per hour must be allowed when there are many bad cases, and especially surgical cases with open wounds; and during epidemics, or when hospital gangrene, pyæmia, or erysipelas are spreading, 6000 cubic feet at least must be given; or, in other words, the supply must be almost unlimited. The best surgeons now consider an almost complete exposure of pyæmic patients to the open air the best treatment; and it is well known that in typhus fever and (to a less extent) in typhoid, and also in smallpox and plague, this complete exposure of patients to air is the first important mode of treatment, before even diet and medicines.

SECTION II.

THE MODE IN WHICH THE NECESSARY QUANTITY OF FRESH AIR CAN BE SUPPLIED.

This is an engineering problem, and there can be no doubt that in time to come it will be as carefully considered by engineers as the supply of water, or the removal of the solid and fluid excreta. Ventilation is, in fact, the problem of the removal of the gasiform excreta of the lungs and skin.

Sub-Section I.—Preliminary Considerations.

1. *Cubic Space.*†—A certain amount of fresh air has to pass through a given air space in a fixed time in order to maintain a certain degree of purity; the amount has been fixed (page 120) at 3000 cubic feet for each adult healthy male in an hour; before considering the appliances for moving this air, we must consider what should be the minimum size of the air space for each healthy male adult through which the fresh air has to pass.

This will entirely depend on the rate at which air can be taken through the space without the movement being perceptible or injurious. The size of the space is chiefly of consequence, as it affects this condition. The larger the air space the less is the necessity for the frequent renewal of air, and the less the chances of draught. Thus a space of 100 cubic feet must have its air changed thirty times in an hour, if 3000 cubic feet of air are to be given, while a space of 1000 cubic feet need only have it changed three times in an hour for an equal ventilation.

When the most perfect mechanical means are employed, the air of even a small air space can be changed sufficiently often without draught. Thus in Pettenkofer's experimental room at Munich, the air space is 424 cubic feet,

* Etude Comparative des Deux Systèmes de Chauffage et de Ventilation, &c. Par C. Grassi, 1856, p. 12.

† For the rules on the measurement of cubic space, see the chapter on the Examination of Air.

and 2640 cubic feet can be drawn through by a steam engine in an hour without perceptible movement; in other words, the change is six times per hour nearly. With the best mechanical contrivances, and with disregard of cost, we are therefore certain that a cubic space of 424 feet would be sufficient, and there is every probability that engineers could ventilate even a smaller space without perceptible movement.

But if the mechanical contrivances are of an inferior kind, and particularly if natural ventilation is used, the difficulties of ventilating a small space are considerable, and are caused not so much by the rate of movement of the greater part of the air in the room, as by the rate at the openings where the fresh air comes in very quickly, and causes currents in the room. Suppose, for example, a space of 500 cubic feet with a man in it, who has to be supplied with 3000 cubic feet in an hour; if the inlet opening be 12 square inches, the rate of movement through it would be 10 feet per second, or nearly 7 miles per hour; if 24 square inches, it would be 5 feet, or about 3·4 miles per hour. In either case, in such a small room, the air could not be properly distributed before reaching the person, and a draught would be felt. It would be necessary to have the inlet larger, but then with natural ventilation there would be a difficulty of control, and too much fresh air would at times be admitted.

If instead of 500 cubic feet 1000 were given, the problem is easier, for the small current of fresh air mixing with the larger volume of air in the room is more easily broken up, and the man being further from the opening the movement is less felt. The question, in fact, turns in great measure on the power of introducing the air without draught.

If the change of air is carried on by what is termed natural ventilation, and under the ordinary conditions of this climate, a change of air six times per hour, as in Pettenkofer's room, could not be attempted. Even five times per hour would be too much, at least in barracks with 600 cubic feet per head, the rooms are cold and draughty, when anything approaching to 3000 cubic feet per head per hour are passing through; that is a change of five times per hour for each 600 cubic feet of air space. A change equal to four or three times per hour is, I believe, generally all that can be borne under the conditions of warming in this country, and if this be correct, from 750 to 1000 cubic feet should be the minimum allowance of the initial air space.*

With good artificial ventilation and an equable movement, which, however, is not always easy to get, there might be larger inlets, and therefore more easy distribution and a smaller air space to begin with. If the inlets are 48 square inches, the rate through them to supply a space of 500 cubic feet with 3000 cubic feet per hour, would be only $2\frac{1}{2}$ feet per second; and if, as should be the case in artificial ventilation, the inlet is 72 or 80 square inches in size, the rate would only be a little over $1\frac{1}{2}$ foot per second, which would be quite imperceptible even at the orifice. But there is an argument against a small cubic space even with good mechanical ventilation, viz., that if anything arrests the mechanism for a time, the ratio of impurity from respiration increases much faster in a small than a large space.†

Some other conditions have also to be considered. The warmth of the moving air influences the sensation of the persons exposed to it. At a

* It will, of course, be perceived that the whole argument turns on the assumption of the correctness of the standard of practicable purity, viz., ·6 volumes of carbonic acid per 1000. If a less pure standard is fixed, the amount of fresh air per hour would of course be less; but I hope the purer standard will be adopted.

† Experimental data on many of these points are still wanting. In prisons, with cells for separate confinement and artificial ventilation, the amount of space is seldom under 750 to 800 cubic feet, and practically this is found to be too small.

temperature of 55° or 60°, a rate of $1\frac{1}{2}$ feet per second (= 1 mile per hour nearly) is not perceived; a rate of 2 and $2\frac{1}{2}$ feet per second (1·4 and 1·7 miles per hour) is imperceptible to some persons; 3 feet per second (2 miles per hour nearly) is perceptible to most; a rate of $3\frac{1}{2}$ feet is perceived by all persons; any greater speed than this will give the sensation of draught, especially if the entering air be of a different temperature, or moist. If the air be about 70° Fahr., a rather greater velocity is not perceived, while if it be still higher (80° to 90° Fahr.), the movement becomes again more perceptible, and this is also the case if the temperature be below 40° Fahr. If the air could be warmed to a certain point, in a cold climate, or if the climate be warm, there may be a much more rapid current, and consequently a smaller cubic space might be given. The subject of ventilation is in cold climates connected inseparably with that of warming. (See chapter on WARMING.)

The above remarks apply to adult males; for women and children it might be considered that the amount of fresh air and the amount of cubic space should be less, as they vitiate the air less than men. But as the difference between women and men is not great, and as children, in proportion to their size, undergo a more rapid tissue change than adults, it would be the safest course to have the same rule for all individuals of whatever age, except the very youngest and oldest, who require special conditions of warming. Some persons, however, class two children as one adult; but if this be adopted, the rule should, at any rate, be restricted to children under five years old.

The amount of cubic space thus assigned for healthy persons is far more than most people are able to have; in the crowded rooms of the artizan class, the average entire space would probably be more often 200 or 250 cubic feet per head than 800. The expense of the larger rooms would, it may be feared, be fatal to the chance of such an ideal standard being generally carried out; but, after all, the question is, not what is likely to be done, but what ought to be done; and it is an encouraging fact that in most things in this world, when a right course is recognised, it is somehow or other eventually carried out.

So in the case of soldiers, the amount of authorised regulation space (600 cubic feet), is below the standard now given, but still the space is as much as can be demanded at present. It has been found very difficult, without incurring greater expense than the country would bear, to give every man even the 600 cubic feet, and as soldiers are healthy men, and can bear rapid movement of air, and as some of the entering air is warmed by the barrack grate, the 600 cubic feet may possibly suffice.

For sick persons the cubic space should be more than for healthy persons. We are to remember that there are other impurities besides those arising from respiration and transpiration, and that immediate dilution and as speedy removal as can be managed are essential.

Dr Angus Smith has forcibly argued for very quick removal in cases of disease,* and there can be no doubt he is correct in principle; but this must be done without perceptible movement, as surface chilling has to be carefully avoided. Very much the same considerations apply to sick as to healthy men, except that the allowance of air in all cases of acute disease must be greater; and, therefore, especially if natural ventilation be employed, the cubic space has to be enlarged also, to insure good distribution without draught.

Admitting that on an average 4000 cubic feet of fresh air should be sup-

* See his paper in the Report of the Committee appointed to inquire into the cubic space of Metropolitan Workhouses, 1867, p. 27.

plied per patient per hour, and if the change of air is to be four or three times per hour, as the best rate of movement, the cubic space must be 1000 or 1300 cubic feet respectively. A consideration of another kind may aid in determining the question as regards sick men. In hospitals a certain amount of floor space is indispensably necessary; first, for the lateral separation of patients; secondly, for convenience of attendance. For the first object the greater floor space the better; and in respect of the second, Dr Acland has clearly shown that the *minimum* floor space for convenient nursing should be 72 square feet per bed.* In a ward of 12 feet in height this would give 864 cubic feet.

Considering, however, the immense benefit to patients of pure air, and the practical experience of hospital physicians, it is very desirable not to fix the floor and cubic space of hospital wards intended for acute and surgical diseases, and for cases with copious discharges, at the minimum of what may suffice. The general tendency of hospital physicians and surgeons is to obtain for their patients, if they can, a floor space of 100 to 120 square feet, and a cubic space of 1500 to 2000 cubic feet, and I believe that this is true wisdom.

The amount of ventilation for animals has not been experimentally determined to my knowledge. A horse is said to require at least 2466 cubic feet of fresh air per hour, but he probably requires more, and the analysis of the air of stables shows that the air has frequently been very impure. At present, the Army Regulations allow, in new stables, each horse 1605 cubic feet, and 100 square feet of floor space;† and the means of ventilation, as will be presently noticed, are ample. In the new Army Horse Infirmaries the superficial area is to be 137 square feet, and the cubic space 1900 feet per horse.

In the stables of cattle there is often excessive over-crowding, and it is well known that there is a vast amount of disease among them, which, however, is seldom allowed to go far, as they are sent to the butcher. Dr Ballard, who paid great attention to the cattle plague in Islington, recommended that at least 1000 cubic feet should be allowed per animal.

2. *Source of the air supplied.*—In order that the object of the ventilation shall not be defeated, it is necessary that the air entering a room shall be pure. The air must be the pure external air, and not be derived from places where it has stagnated and taken up impurities; if it is drawn along passages or tubes, and through louvres or basements, these should be capable of inspection and cleansing. All air-shafts should, if possible, be short and easily cleaned. I have seen several instances of air being distributed by costly appliances, and yet being drawn from an impure source, or allowed to be contaminated on its passage. Instead of perforated bricks, there should be sliding panels on hinged flaps, so that the tube may be easily reached.

3. *Warming or cooling of the air.*—The air may require to be warmed to 60° or 65° Fahr., or cooled according to the season or locality.

4. *Distribution.*—The distribution in the rooms should be perfect, that is, there should be uniform diffusion of the fresh air through the rooms. Much difficulty is found in properly managing this, and it requires careful arrangement of the various openings. The distributing plans should, if possible, prevent the chance of breathed air being rebreathed, especially in hospitals. As the ascent of expired air is rapid, on account not only of its temperature, but from the force with which it is propelled upwards with patients in bed, the point of discharge should be above.

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* See Report of the Committee appointed to inquire into the cubic space of Metropolitan Workhouses, 1867, p. 12.

† Report of the Barrack and Hospital Improvement Commission on the Ventilation of Cavalry Stables, 1863, p. 10.

During the last few years it has been argued that it is better that the foul air should pass off below the level of the person, so that the products of respiration will be immediately drawn down below the mouth, and be replaced by descending pure air. But the resistance to be overcome in drawing down the hot air of respiration is so great that there is a considerable waste of power, and the obstacle to the discharge is sometimes sufficient, if the extracting force be at all lessened, to reverse the movement, and the fresh air forces its way in through the pipes intended for discharge—a fact which has been noticed in the Hospital Lariboisière on some occasions. This plan, in fact, must be considered a mistake. The true principle is that stated long ago by D'Arcet. In the case of vapours or gases the proper place of discharge is above; but heavy powders, arising in certain arts or trades, and which from their weight rapidly fall, are best drawn out from below.

Sub-Section II.—Means by which Air is set in Motion.

These are :—1*st*, The forces continually acting in nature, and which produce what has been termed natural ventilation. 2*d*, The forces set in action by man, and which produce the so-called artificial ventilation.

The division is convenient, but not strictly logical, as the forces which act in natural do so also in artificial ventilation to a certain extent.

Natural Ventilation—General Statements.

Three forces act in natural ventilation, viz., diffusion, winds, and the difference in weight of masses of air of unequal temperature.

1. diffusion.

As every gas diffuses at a certain rate, viz., inversely as the square root of its density, there is a constant escape of any foreign gas into the atmosphere at large. From every room that is not air-tight Pettenkofer and Roscoe have shown that diffusion occurs through brick and stone, and Pettenkofer believes that one of the evils of a newly built and damp house is that diffusion cannot occur through its walls. But the ordinary plastered and papered walls reduce diffusion to a most insignificant amount. Through chinks and openings produced by imperfect carpentry the air diffuses fast, and Roscoe found that when he evolved carbonic acid in a room the amount had decreased one-half from that cause in 90 minutes.

The amount of purification produced by diffusion under ordinary circumstances is shown by observation to be insufficient, and, in addition, organic substances, which are not gaseous, but molecular, are not affected by it. As a general ventilating power it is therefore inadequate.

2. the action of the winds.

The wind acts as a powerful ventilating agent, and in various ways. If it can pass freely through a room, with open doors and windows, the effect it produces is immense. For example, air moving only at the rate of 2 miles an hour (which is almost imperceptible), and allowed to pass freely through a space 20 feet wide, will change the air of the space 528 times in one hour. No such powerful action as this can be obtained in any other way.

The wind will pass through walls of wood (single-cased), and even of porous bricks or stone, even when the velocity is not great; and perhaps this will account for the fact, that such houses, though cold, are healthy habitations. Pettenkofer has shown, in fact, that the particles of air in brick or

stone are so easily influenced, that by a little arrangement a candle may be blown out on one side of a brick wall by blowing air into the brick on the other side. Plaster, however, appears to arrest wind, if it be true, as stated, that in the interior of some thick walls, after many years, lime has been found still caustic.

There are two objections to winds as ventilating agents by perflation.

1. The air may be stagnant. In this country, and, indeed, in most countries, complete quiescence of the air for more than a few hours is scarcely known. Air is called "still" when it is really moving 1 or 1½ mile an hour. The average annual movement of the air in this country is from 6 to 12 miles per hour, but it varies, of course, greatly from day to day, and in different places. The mean movement at Netley is about 10½ per hour;* at Aldershot, as appears from the careful observations of Sergeant Arnold, it is 12½ miles per hour (mean of 5 years.)

2. A much more serious evil is the uncertainty of the movement, and the difficulty of regulation. When the velocity reaches 5 or 6 feet per second, unless the air be warm, no one will bear it. The wind is therefore excluded, or, if allowed to enter directly through small openings, is badly distributed. Passing in with a great velocity, it forces its way like a foreign body through the air in the room, causing draughts, and escaping, it may be, by some opening without proper mixing. I have measured a current entering in this way for many feet. In spite of this inconvenience, there can be no doubt that in every case, when it can be done, a thorough cross-ventilation by opposite windows should be provided.

But the wind acts in another way. A moving body of air sets in motion all air in its vicinity. It drives air before it, and, at the same time, causes a partial vacuum on either side of its own path, towards which all the air in the vicinity flows at angles more or less approaching right angles. In this way, a small current moving at a high velocity will set in motion a large body of air.

The wind, therefore, blowing over the tops of chimneys causes a current at right angles to itself up the chimney, and the unequal draught in furnaces is owing, in part, to the variation in the velocity of the wind. Advantage, therefore, can be taken of this aspirating power of the wind to cause a movement of air up a tube. And in this way the wind may be made to do excellent service in ventilation.

The wind, however, may impede ventilation by obstructing the exit of air from any particular opening, or by blowing down a chimney or tube. This is, in fact, one reason of the failure of so many systems of ventilation; they may work well in a still atmosphere, but the immense resistance of the wind has not been taken into account, and the plan which works beautifully in a model fails on the large scale.

In some systems of ventilation the perflating power of the wind has been used as the chief motive agent. In Egypt the wind is allowed to blow in at the top of the house through large funnels. This plan has been in use from time immemorial. This was the case in Mr Sylvester's plan, which was used at Derby and Leicester forty or fifty years ago. A large cowl, turning towards the wind, was placed in a convenient spot near the building to be ventilated —a little above the ground if in the country, or at some height if in a town. The wind blowing down the cowl passed through an underground channel to the basement of the house, and entered a chamber in which was a so-called cockle-stove, or calorifère of metal plates, or water or steam pipes, by which the air was warmed. It then ascended through tubes into the rooms above,

* This is probably under the truth, as the anemometer was not well placed when these observations were made. The Aldershot observations are quite correct.

and passed out by a tube or tubes in the roof, which were covered by cowls turning from the wind. So that the aspiratory power of the air was also used. This plan is extremely economical and successful. The movement of air is, however, necessarily unequal, and it is difficult to regulate it. It has been proposed to place a fan in the tunnel to move the air in periods of calm, and the plan then becomes identical in principle, and almost in detail, with the method of Van Hecke.

Mr Ritchie* has employed a similar plan in the ventilation of a dwelling-house. The air is warmed in winter to about 70° Fahr.; every room has a longitudinal opening over each door, concealed by the architrave, and regulated by valves, and through this the warm air from the staircase enters the rooms, and then passes up the chimney, and up outlet air-flues placed in the walls, commencing at the ceiling, and ending at the wall-heads under the roof.

Dr Arnott ventilated the Field Lane Ragged School on this principle with excellent effect, as is shown by the annexed cut. In this case, as in all others the movement is also in part carried on by the third cause of motion in air, viz., the effect of unequal density of masses of air.

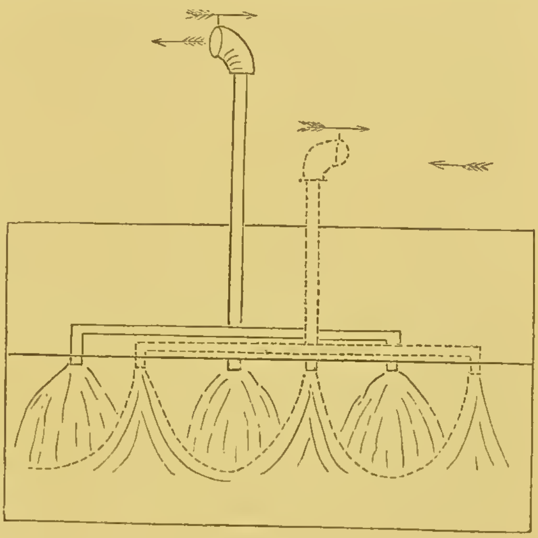

Fig. 10.

In the ventilation of ships, the wind is constantly used; and by wind-sails and tubes with cowls turning towards the wind, air is driven between decks and into the hold.

In using the wind in this way, the difficulty is to distribute the air so that it shall not cause draughts. This is best done by bending the tubes at right angles two or three times, so as to lessen the velocity, by enlarging the channel towards the opening in the interior of the vessel, and by placing valves to partially close the tubes, if necessary, and by screens of wire-gauze.†

In all cases in which the air of a room, as in a basement story, or in the hold of a ship perhaps, is likely to be *colder* than the external air, and when artificial means of ventilation cannot be employed, the wind should be taken advantage of as motive agent.

The aspiratory power of the wind can be secured by covering air-shafts with moveable cowls turning from the wind, and special forms of covering hereafter described, which aid up currents and prevent down draughts.

3. MOVEMENTS PRODUCED BY UNEQUAL WEIGHTS OF AIR.

The wind itself is caused by this power; but it is necessary, in discussing ventilation, to look upon this as if it were an independent force. If the air in a room be heated by fire, or the presence of men or animals, or be made

* Treatise on Ventilation, by Robert Ritchie, C.E., 1862, p. 89.

† As the use of perforated zinc plates and of wire-gauze is very common in ventilation, it is necessary to bear in mind that these screens very soon get clogged with dirt. In all cases they should be so arranged as to be easily inspected and cleaned; and it should be a matter of routine duty to see that they are constantly kept clean. It should also be understood that the delay by friction through the fine wire-gauze is exceedingly great. I believe it is better to avoid their use as much as possible.

moister, it endeavours to expand; and if there be any means for it to escape, a portion of it will do so, and that which remains will be lighter than an equal bulk of the colder air outside. The outer air will then rush into the room by every orifice, until the equality of weight outside and inside is re-established. But as the fresh air which comes in is in its turn heated, the movement is kept up in a constant stream, cold air entering by one set of orifices, and hot air escaping by another.

We have now to inquire how the rate of this constant stream of air may be calculated.* The mode most generally used is based on two well-known laws: first, that the velocity in feet per second of falling bodies is equal to (nearly) 8 times the square root of the height through which they have fallen; and, second, that fluids pass through an orifice in a partition with a velocity equal to that which a body would attain in falling through a height equal to the difference in depth of the fluid on the two sides of the partition.† The pressure of air upon any surface may be represented by the weight of a column of air of uniform density of a certain height. Thus the pressure of the atmosphere at the surface of the earth is 14 lbs. on the square inch, and this would be the weight of a column of air of about 5 miles in height. Air, therefore, rushes into a vacuum with a velocity equal to that which a heavy body would acquire in falling from a height of 5 miles, viz., 1339 feet per second. But if, instead of rushing into a vacuum, it rush into a chamber in which the air has less pressure than outside, its velocity will be that due to a height which represents the difference of pressure outside and inside. In ordinary cases this difference of pressure cannot be obtained by direct observation, but must be inferred from the difference of temperature of the outer and inner air. Air is dilated one part in 491 of its volume for every degree of Fahrenheit that its temperature is raised, consequently the difference of pressure outside and inside will be as follows:—

The height from the aperture at which air enters to that from which it escapes, multiplied by the difference of temperature outside and inside, and divided by 491.

If the height be 20 feet, and the difference of temperature 15 degrees, we have the height to produce velocity of inflowing current $= \frac{20 \times 15}{491} = 0{\cdot}61$ of a foot, and the velocity $= 8\sqrt{\cdot 61} = 8 \times \cdot 781 = 6{\cdot}248$. This, however, is the theoretical velocity. In practice an allowance must be made for friction of $\frac{1}{4}$, $\frac{1}{3}$, or even $\frac{1}{2}$, according to circumstances. The diminution of velocity from friction is in proportion to the length of the tube, and is inversely as the diameter. Right angles greatly increase the friction. The friction increases also as the square of the velocity. The deduction of $\frac{1}{4}$th would leave 4·686 linear feet per second as the actual velocity. If this be multiplied by the area of the opening, in feet, or decimals of a foot,‡ the amount of air is expressed in cubic feet per second, and multiplying by 60 will give the amount per minute.

A table is given at page 153, in which this calculation has been made for

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* Many of these points are given in Hood's Treatise on Warming and Ventilation, and in Wolpert (*Principien der Vent. und Luftheizung*), and are also discussed in Péclet (*Traité de la Chaleur*, 3d edit.), and by General Morin (*Études sur la Ventilation*, Paris, 1863, t. xi.), to which reference is made for those who wish to enter into the mathematical part of the inquiry.

† This is frequently called the Rule of Montgolfier. The formula is $v = \sqrt{2gH}$: g being the acceleration of velocity in each second of time, viz., 32·18 feet, and H the height of the descent.

‡ It will be found always easier to take the area in decimals of a foot instead of inches; but if it be taken in inches, multiply the linear discharge by the number of square inches, and divide by 144.

all probable temperatures and heights, but it must be remembered that the movement is greatly influenced by the wind.

This cause of movement is, of course, constantly acting when the temperature of the air changes. It will alone suffice to ventilate all rooms in which the air is hotter than the external air, but will not answer when the air to be changed is equal in temperature to, or colder than, the external air.

As its action is equable, imperceptible, and continuous, it is the most useful agency in natural ventilation in cold climates, in inhabited and warm rooms; and in all habitations arrangements should be made to allow it to act. As the action increases with the difference of temperature, it is most powerful in winter, when rooms are artificially warmed, and is least so, or is quite arrested in summer, or in hot climates, when the internal and external temperatures are identical.

How powerful its action is may be seen from the following statement:— At the Hospital Lariboisière in Paris, a powerful fan is used to drive air into some of the wards, at a considerable expense. It has been lately shown by General Morin that the movement of air in the wards is, however, chiefly produced by natural ventilation, arising from difference of temperature. Only 14·9 per cent. was on an average due to the fan, and in two experiments it was as low as 12·4 per cent. No less than 85·1 per cent. of the movement was from natural ventilation.

4. PRACTICAL APPLICATION OF THE GENERAL STATEMENTS ON NATURAL VENTILATION.*

1. No particular arrangements are necessary to allow diffusion to act except that there shall be communication between two atmospheres.

2. To obtain the perflation of the wind, windows should be placed, in all cases where it can be managed, at opposite sides of a room. The windows should open at the top, and in case the wind has a high velocity, means should be taken to distribute it. This can be done by sloping the window inwards when it opens, a plan which answers admirably at the Middlesex Hospital, where the windows are divided into three parts, which open slopingly by a lever and pivot. A board may be placed obliquely upwards from the top sash of the window, when it opens in the usual way; then the air striking against the board is thrown up towards the ceiling. The Patent Ventilating Company use a wire screen, which folds up when the window is shut, and unfolds when the window is pulled down. The velocity of the wind is checked by the gauze, and the current is minutely divided. All these plans are good, especially the one adopted in the Middlesex Hospital.

Various plans have been proposed by different persons. The panes of glass may be made double, spaces being left at the *bottom* of the outside pane, and at the *top* of the inner one, so that the wind is obliged to pass up between the two panes before it enters the room. Or, the lower sash being raised, and a piece of wood placed below it, the air is allowed to pass through the space left between the upper and lower sashes. Or, glass louvres, which can be more or less closed, are placed in one of the panes of the window; or a number of holes are obliquely bored through the panes, through which the air may pass up towards the ceiling before it intermixes with the air of the room. In Lockhead's ventilator there is a frame over the glass louvre, with a regulator in the centre. In Cooper's ventilator a moveable plate of glass can be brought by a moveable handle over the opening.

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* A very good account of the various plans in natural ventilation will be found in Mr Edward's work, "On the Ventilation of Dwelling-houses," 1868, in which figures of the plans are given.

Besides windows, special openings may be provided for the wind to blow through, as in the plans already referred to of Mr Sylvester and Dr Arnott.

In all warm climates, where no chill can be produced by wind, it is a good plan to make the walls entirely pervious. Nothing can be better than the ventilation of the bamboo-matted houses in Burmah. The wind blows through them, but is so broken up into currents that it is not in the least unpleasant. Even in colder parts of India the upper parts of the walls might be made thus pervious, provision being made to cover them, if necessary, in the cold season.

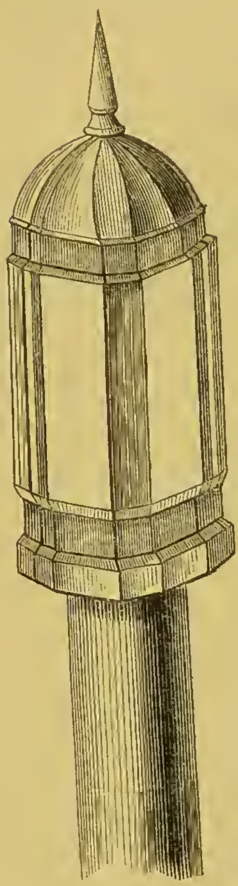

Fig. 11.

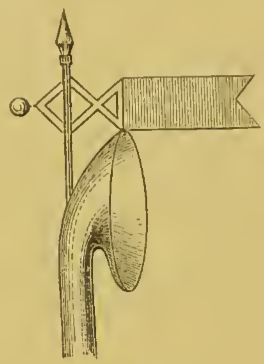

Fig. 12.

Fig. 13.
Section of Fig. 11.

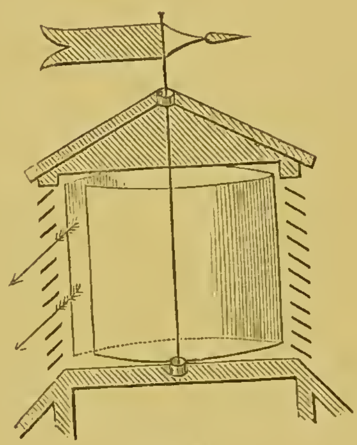

Fig. 14.

To obtain the full effect of the aspirating power of the wind, chimneys or ventilating tubes should be fitted with cowls turning away from the wind. The cowl should be large, and should expand greatly towards the end, so as to make the calibre of the opening several times greater than that of the tube (fig. 12). Most cowls on chimneys are too small. The upper rim should also project a little, so as to lessen the chance of rain getting in.

Another form of covering is represented in fig. 11, and is also drawn in section (fig. 13). Whichever way the wind blows it almost always causes an up-draught. A little rain, however, may possibly penetrate, but otherwise it is as good as the cowl.

Louvred openings are not nearly so good; the aspirating effect is much less, down-draughts are common, and rain gets in. If louvres are used, a plan invented by Mr Ritchie is a good one.* Inside the louvre is a moveable cylin-

* Péclet (*op. cit.* t. i. p. 241) figures a variety of chimney coverings, and many others have been proposed.

der, turning with a vane; on the side *opposite* the wind is an opening through which the air escapes (fig. 14).

3. The movement produced by the difference of weight of unequally heated bodies of air will, of course, go on through open windows and doors, and through all the contrivances just mentioned. But as in cold climates windows and doors must sometimes be shut, no room of any kind should be without additional openings, which may permit this movement from unequal temperature to go on. The great difficulty here, is to exclude the action of the wind; and, in fact, it is impossible to do so; but, as far as possible, the openings should be protected from the perflating influence of the wind, so that only its aspirating force should be acting. They should be capable of being lessened in size, when the difference of the external and internal temperatures is great. As long as there are openings, movement will go on; and it does not really matter, as long as there is proper distribution, where the air comes in or goes out, or whether its direction is constant. In fact, it scarcely ever is constant, so liable is the direction to be altered by winds, by the action of the sun heating one side of a room, by the unequal distribution of heat in the room, &c. Still it seems desirable, as far as it can be done, to make such arrangements as shall give the movement of air a certain direction; and therefore, in most systems, some of the openings are intended for the admission of fresh air. These are called inlet, entrance, or adduction openings; others are intended for the discharge of impure air—exit, outlet, or abduction openings.

Total size of all the special openings, whether intended for Inlets or Outlets.—As the movement of air increases with temperature, the size of the apertures can only be fixed for a certain given temperature; and as the efflux of hot air increases with the height of the column (supposing the temperature is equal throughout), a different size has also to be fixed for different heights.

This causes a difficulty in fixing the proper size for ventilating openings in the case of natural ventilation, as the conditions are so variable. The theoretical size for any required change of air, supposing the conditions were constant, may be obtained from the table at page 153, which is calculated from Montgolfier's formula, with a deduction of $\frac{1}{4}$ for friction.

Thus, say that the height of the heated column is 20 feet, and the difference of temperature between the air in the room and that outside is 20°, the linear rate of discharge as stated by the table (allowance being made for friction) is 322 feet per minute, or 19,320 feet per hour. If the opening were 1 square foot, this would give 19,320 cubic feet per hour. But if 3000 cubic feet per hour are wanted for one man, the orifice of 1 square foot or 144 square inches is too large, and must be lessened in the proportion of 3000 to 19,320. $\frac{3000 \times 144}{19,320} = 22$ square inches (round numbers), *i.e.*, reduced to 22 square inches. There must be a corresponding space for entry, making the total ventilating opening 44 square inches.

To take another example; let us say the heated column is 15 feet, the difference of temperature 10°, and the required supply for one man, 2000 cubic feet. The table gives the linear rate as 197 feet per minute, or 11,820 per hour; an orifice of 144 square inches would then give 11,820, and an orifice of 24 square inches would give 2000 $\left(\frac{2000 \times 144}{11,820} = 24\right)$. But if in the above conditions 3000 cubic feet hourly supply were wanted, the opening must be 36 square inches. These examples show how impossible it is to fix any size which shall meet all conditions, even if the influence of wind could be completely

excluded, which is impossible. The only way is to adopt a size which will meet most cases, and supply means of altering the size according to circumstances. In this country, a size of 24 square inches per head for inlet, and the same for outlet, seems calculated to meet common conditions; but arrangements should be made for enabling this to be lessened or closed in very cold weather, or if the influence of strong winds is too much felt.* Moreover, the size must be in part dependent on the size of the room, because in a small room with many people it is impossible to have the size so great as it would be if each person's space were 48 square inches, unless some portion of the air were warmed.

Relative size of the Inlets and Outlets.—It is commonly stated that, as the heated air expands, the outlets should be larger than the inlets, and the great disproportions of 5 to 4 and 10 to 9 have been given. As, however, the average difference of temperature is only about 10° to 15° Fahr. in this country, the disproportion is much too great, as a cubic foot of air only expands to 1·020361 cubic feet with an increase of 10°. Even if the difference is 30° Fahr., a cubic foot of air only becomes 1·061 cubic feet, which is equal to an increase of about $\frac{1}{17}$th. The difference is so slight that it may be neglected, and the inlets and outlets can be made of the same size.

It is desirable to make each individual inlet opening not larger than 48 to 60 square inches in area, or enough for two or three men; and to make the outlet not more than 1 square foot, or enough for six men. Distribution is more certain with these small openings.

Position and Description of the Inlet and Outlet Tubes.—1. *Inlets.*—The air must be taken from a pure source, and there must be no chance of any effluvia passing in. As a rule, the inlet tubes should be short, and so made as to be easily cleaned, otherwise dirt lodges, and the air becomes impure. Inlets should not be large and single, but rather numerous and small (from 48 to 60 inches superficial), so that the air may be properly distributed. They should be conical or trumpet-shaped, where they enter the room, as the entering air, after perhaps a slight contraction, spreads out fan-like, and a slight back-current from the room down the sides of the funnel facilitates the mixing of the entering air with that of the room. To lessen the risk of immediate

* The following formula proposed by Dr de Chaumont can be used instead of the table at page 153. No correction is made for friction, and therefore the sizes should be increased in the proportion of 3 to 4 if the outlets are long. It is based on Montgolfier's formula, with the discharge calculated for the hour and for square inches, instead of for the minute and the linear discharge, as in the table.

Let h be the height of the heated column of air; t its temperature; t' the temperature of the external air; ·002 the ratio of expansion of air for each degree of Fahr.; and 100 a constant. Let D be the delivery required per hour, and Φ the total inlet and outlet area in square inches. Then to find Φ:

$$\frac{D}{100\,(\sqrt{h\,(t-t')\times \cdot 002})} = \Phi.$$

Example: Suppose, as in the text, that the heated column be 20 feet, its mean temperature 65°, and that of the outer air 45°, and the required delivery be 3000 cubic feet per hour;

$$\frac{3000}{100\,(\sqrt{20\,(65^\circ-45^\circ)\times \cdot 002})} = 33\cdot 5$$

square inches for inlet or outlet, or 16·75 for inlet alone. Increasing this on the supposition that a quarter of the velocity is destroyed by passage through a long tube, the size of the inlet opening will be 22 square inches (round numbers).

A converse formula by Dr de Chaumont may be also useful. If the area of the inlet opening (Φ') is known, to find the delivery per hour under conditions h, t, and t'.

$$200\,(\sqrt{h\,(t-t')\times \cdot 002})\,\Phi' = D.$$

The constant 200 is obtained by multiplying 3600 (seconds per hour) by twice the square root of 16·09 (= 8 nearly), and dividing by 144 square inches. By halving this constant we get the number for both inlet and outlet together.

down-draught they should turn upwards, if they are placed above the heads of the persons. Externally the inlets should be partly protected from the wind; otherwise the wind blows through them too rapidly, and, if the current be strong, draughts are felt; an overhanging shelf or hood outside will answer pretty well. Valves must be provided to partially close the openings if the wind blows in too strongly, or if the change of air is too rapid in cold weather. In many cases (for example, when they enter at the bottom of a room, and the air is not warmed) the tubes should be covered with wire-gauze, so as to break up the entering current into small streams; but the openings must not be too small, otherwise friction may be great enough to check the entrance. The wire-gauze must be frequently cleaned.

Sometimes an inlet tube must be carried some distance to an inner room, or to the opposite side of a large room which is unprovided with cross-ventilation. In this case the heat of the room so warms the tube that the wind may be permitted to blow through it.

The position of the inlets is a matter of some difficulty. If there are several, they should be, of course, equally distributed through the room, so as to insure proper mixing of the air. They should not, however, be placed too near an outlet, or the fresh air may at once escape; theoretically, their proper place of entrance is at the bottom of the room, but if so, the air must in this climate be warmed; no person can bear the cold air flowing to and chilling the feet. The air can be warmed easily in various ways, viz.—

(*a.*) The air may pass through boxes containing coils of hot-water pipes, or (in factories) of steam pipes. This is the best mode of warming. The coils may be close to the outside wall, or in the centre, or in hospitals in boxes under the beds, communicating with the exterior air, and opening into the ward. This is an excellent plan, as the confined space below the bed, and the bed itself, are purified, and the fresh air rising on both sides of the bed at once dilutes the air of respiration and transpiration. (See Hospitals.)

(*b.*) The air may pass into air chambers behind or round grates and stoves, and be there warmed, as in the present barrack and hospital grate, contrived by Captain Galton; or as in the Meissner or Böhm stove of Germany; or as in the terra cotta stove, in the Herbert Hospital at Woolwich. (See Warming.)

(*c.*) The tubes may be made to run for some distance inside the room, so that they may become warm; metal tubes answer best for this purpose, and they should be small.

If the air cannot be warmed, it must not be admitted at the bottom of the room; it must be let in above, about 9 or 10 feet from the floor, and be directed towards the ceiling, so that it may pass up and then fall and mix gradually with the air of the room. The Barrack Commissioners have adopted this plan with half the fresh air brought into a barrack-room. The other half is warmed. It answers very well.

The fresh air may be introduced at the top of the room, as in M'Kinnell's plan, and, if properly distributed, this arrangement answers very well. But both these last modes must be considered inferior to the first, if the air can be warmed.

In towns or manufacturing districts the air is so loaded with particles of coal, or, it may be, other powders, that it must be filtered. Nothing answers better for this than muslin or thin porous flannel, or paperhangers' canvas, spread over the opening, which then should be made larger. This covering can be moistened if the incoming air be too dry.

2. *Outlets.*—The place for the outlets is a most important consideration, as it will determine in great measure the position of the inlets. If there are no

means of heating the air passing through them, they should be at the top of the room; if there are means of heating them, they may be at any point. If not artificially warmed, the highest outlet tube is usually the point of greatest discharge, and sometimes the only one.

(*a*.) *Outlet Tubes without Artificial Heat.*—They should be placed at the highest point of the room; should be enclosed as far as possible within walls, so as to prevent the air being cooled; should be straight and with perfectly smooth internal surfaces, so that friction may be reduced to a minimum. In shape they may be round or square, and they must be covered above with some apparatus (the cowl, hexagon tube, &c.), which may aid the aspirating power of the wind, and prevent the passage of rain into the shaft (see page 128). The louvred openings are not the best.

The causes of down-draught and down-gusts in outlet tubes are these;—the wind forces down the air; rain gets in, and, by evaporation, so cools the air that it becomes heavier than the air in the room; or the air becomes too much cooled by passage through an exposed tube, so that it cannot overcome the weight of the superincumbent atmosphere; or another outlet shaft, with greater discharge, reverses the current.

Arrangements should be made to distribute the down-draught, if it occurs; flanges placed at some little distance below, so as to throw the air upwards again before it mixes with the air of the room, or simple contrivances of a similar kind, may be used. Valves should be also fixed to lessen the area of the outlet when necessary. If there are several outlet tubes in a room, all should commence at the same distance from the floor, be of the same height (or the discharge will be unequal), and have the same exposure to sun and wind.

Simple ridge openings may be used in one-storied buildings with slanting roofs; they ventilate most thoroughly, but snow sometimes drifts in. Rain may be prevented entering by carrying down the sides of the overhanging ridge for some little distance. A flange placed some little distance below will throw any down-draught towards the walls.

(*b*.) *Outlets with Artificial Warmth.*—The discharge of outlets is much more certain and constant if the air can be warmed. The chimney and open fire is an excellent outlet—so good that in dwelling-houses, if there are proper inlets, no other outlet need be made. When rooms are large, and more crowded, other outlets are necessary; the heat of the fire may be farther utilised by shafts round the chimney, opening at the top of the room, or, in other words, by surrounding the smoke-flue with foul-air shafts.

Gas, if used, should in all cases be made to warm an outlet tube, both to carry off the products of combustion, and to utilise its heat. The best arrangement appears to be to place over the gas-jet a pipe to carry off the products of combustion, and to case the pipe itself with a tube, the opening of which is at the ceiling; the tube carrying off the gas products is hot enough to cause a very considerable draught in its casing, and thus two outlet currents are in action, one over the gas, and one from the ceiling round the gas-tube. A modification of the lamp proposed in 1846 by Mr Rutter answers very well, and is now coming into use, as arranged by Mr Ricketts.

In various other ways the heat of fire and lights may be taken advantage of. There will be seldom any difficulty in arranging the inlets and outlets, and in obtaining a satisfactory result, if these principles are borne in mind, viz., to have the fresh air pure, to distribute it properly, and to adopt every means of securing the outlets from cold or of artificially warming them, and of distributing the air, which, in spite of all precautions, will occasionally pass down them.

In hot climates, when outlet shafts are run up above the general level of the

building, it would be of advantage to make them of brick work, and to colour them black, so that they may absorb and retain heat.

5. PLANS OF TUBES AND SHAFTS WHICH HAVE BEEN PROPOSED.

In most of the plans which have been proposed, the inventors have not distinctly seen that the influence of the winds and of the movement of air produced by unequal temperatures must be carefully distinguished, and, as far as can be done, provided for.

1. *Openings at once to the Outer Air for Inlets, the Chimney being relied on for the Outlet or Special Tubes fixed in.*—Perforated or air bricks are let into the walls. A usual size is 9 × 3 inches, and the united area of all the several openings in one brick is about 11½ square inches. Another common size is 10 × 6 inches, with an open area of about 24 square inches. The wind blows freely through them, and draughts are produced.

The Sheringham valve is a great improvement on this; the air passes through a perforated brick or iron plate, and is then directed upwards by a valved opening, which can be closed, if necessary, by a balanced weight (fig. 15). The size of the internal opening is, in the usual-sized valve, 9 inches by 3, and the area is 27 inches. These valves are usually placed towards the upper part of the room. The wind blows through them, and the movement is therefore variable. They are often outlets; it will, in fact, depend upon circumstances whether they are inlets or outlets. Very little draught is, however, caused by them, unless with a high wind; on the whole, they are the best inlets of this kind.

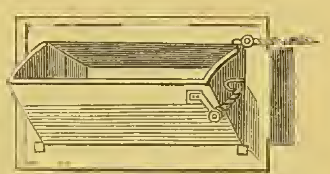

Fig. 15.

An open iron frame of the size of a brick, covered with perforated zinc, and with a valve to close it, if necessary, is a still simpler plan, and the air is pretty well distributed. The gauze should be cleaned frequently. The National Ventilation Company fix folded wire-gauze screens at the top of the windows; when the window is opened, the screen is unfolded. Mr Boyle of London uses a round plate working on a screw, which can be brought nearer or farther from a corresponding opening in the wall; the air entering strikes on the plate, and then spreads circularly over the wall, and is then drawn gently into the room.

2. *Tubes of Different Kinds.*—A single tube has been sometimes used for inlet and outlet, a double current being established. This is, however, a rude plan, as there are no means of distributing the air, and as the intermingling of the current and the friction of the meeting air is sometimes so great as to impede, or even for a time stop, the movement.* To avoid these inconveniences, Watson proposed to place a partition in the tube (fig. 16), and

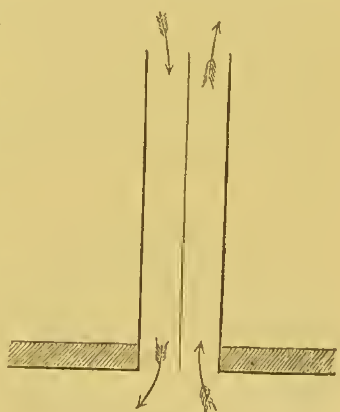

Fig. 16.

* The model of Watson's ventilating tube is well adapted for showing how opposing currents of air block each other. Although the tube is of good size, a candle placed in a bell glass, into the top of which the tube is fixed, soon goes out; a partition being then inserted into the tube, the currents are at once divided—one passes up, one down, the sides of the tube, and the candle burns again.

Muir suggested the use of a double partition running from corner to corner, so as to make four tubes. He covered his divided tube with a louvre, so as to make use in some degree of the aspiratory power of the wind on one side.

In these tubes, accidental circumstances, such as the sun's rays on one side, the wind, the fire in the room, &c., will determine which is outlet and which is inlet. They are so far better than the single tube, that the partition divides the currents and prevents friction, but there is the same irregular action and changing of currents from accidental circumstances, so that the direction of the currents and their rate are variable. The distribution of the entering air is also not good.

Much better than these plans is M'Kinnell's circular tube. It consists of two cylinders, one encircling the other, the area of the inner tube and encircling ring being equal. The inner one is the outlet tube; it is so because the casing of the other tube maintains the temperature of the air in it; and it is also always made rather higher than the other; above it is protected by a hood, but if it had a cowl turning away from the wind, it would be better. The outer cylinder or ring is the inlet tube; the air is taken at a lower level than the top of the outlet tube; when it enters the room, it is thrown up towards the ceiling, and then to the walls by a flange placed on the bottom of the inner tube; the air then passes from the walls along the floor towards the centre of the room, and upwards to the outlet shaft. (Figs. 17 and 18.) Both tubes can be closed by valves. If there is a fire in the room, both tubes may become inlets; to prevent this, the outlet tube should be closed; if doors and windows are open, both tubes become outlets.

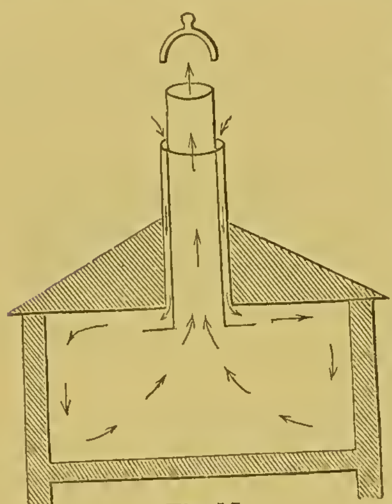

Fig. 17.

The movement of air by this plan is imperceptible, or almost so; it is an admirable mode for square or round rooms, or small churches; for very long rooms it is less adapted.

The tube is made of all sizes, from 6 inches in diameter, which is adapted for a sitting-room, up to 7 or 8 feet, which is the size used in some churches. The two tubes, after passing out of the room, may be taken in different directions, care being taken that the inner tube is always the longest, and, if possible, with the fewest curves.

If the two tubes can be kept together for some distance, an advantage would perhaps be gained, as the hot air would transmit a portion of its heat to the air in the outer tube, which would enter the room at a higher temperature than would otherwise be the case; some loss of movement would result, but this would be trifling.

Dr Arnott's chimney ventilator is a valved opening at the top of the room, leading at once into the chimney, and, like Dr Chowne's siphon, has the great advantage of drawing the air from the top of the room; it has been, and is, much used, but has the inconvenience of occasionally allowing the reflux of smoke.

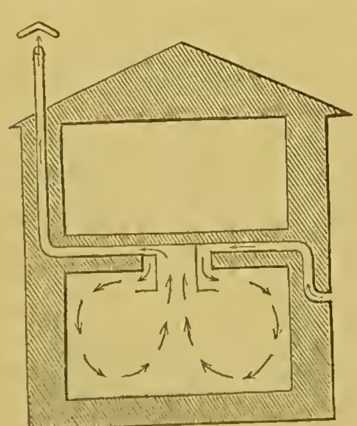

Fig. 18.

Mr Boyle has altered this chimney ventilator by hanging small talc plates at a certain angle; falling by their own weight, they close the opening and prevent reflux, but a very slight pressure from without opens them.

Of these various plans, M'Kinnell's should be chosen, if the air must be admitted at the top of the room; and it is well adapted for guard-rooms, cells, and rooms of small dimensions, when it is desired to have the ventilating apparatus out of reach. Watson's divided tube can also be used, but is less useful than M'Kinnell's.

System of Ventilation Adopted in the Army.

On Home Service.—The official plan now in use was arranged about ten years ago by the Barrack Improvement Commission; it is applied in most of the new barracks, and in several old ones. It has answered extremely well, and it is much to be desired that it should be carried out everywhere. It is based on the plan of natural ventilation, and consists of—

1. An outlet shaft, or more if required, proceeding from the highest point of the room; the exact position in the room varies; it is sometimes at the corner, or at one side, according to circumstances. This shaft is carried straight up inside the walls, and about 4 to 6 feet above the roof, and is covered with a louvre. It is made of wood, is very smooth inside, and is provided with a flap for partly closing it below. Its size is regulated by that of the room and by the number of inmates, but it is not made larger than 1 square foot; if more outlet is required, another shaft is put up. The relation between its size and that of the room varies with the position of the room. In a three-storied barrack the rule is as follows:—

1. On the ground floor, 1 square inch of section area of outlet shaft for every 60 cubic feet of room space,

$$= \text{for each man } \left(\frac{600}{60}\right) \text{ 10 square inches of area.}$$

2. On the first floor, 1 square inch for every 55 cubic feet of room space,

$$= \text{for each man } \left(\frac{600}{55}\right) \text{ 10·9 (say 11) square inches.}$$

3. On the second floor, 1 square inch for every 50 cubic feet of room space,

$$= \text{for each man } \left(\frac{600}{50}\right) \text{ 12 square inches.}$$

In a one-storied barrack the amount should be the same as the second floor, or, in other words, 12 men would have a shaft of 1 square foot. In addition, there is the chimney, which, with Galton's stove, gives a section area per head of about 6 square inches. The total outlet area per man is therefore 16 to 18 inches, according to circumstances.

2. *Inlets.*—The amount of inlet is a trifle more than 1 square inch to every 60 cubic feet of room.

Half the inlet air is warmed in all the new barracks and many old barracks by being taken through air chambers behind the fire (area of tube = 6 square inches per head), and the other half comes direct from the outer air into the rooms through Sheringham valves. Area of outer opening = 5 square inches, making altogether 11 square inches of inlet opening per man.

The cold air inlets (Sheringham valves) are placed at the sides near the

ceiling, about 9 feet from the floor, and are not opposite each other. Fig. 19 shows a usual arrangement. The outlet space is thus seen to be rather larger than the inlet, but as the doors and windows seldom fit close, it is probable that practically this is of little consequence.

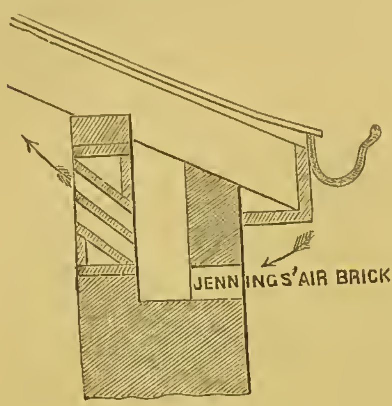

Fig. 19.

The movement of air through these openings is tolerably regular—as regular as it ever can be in natural ventilation. The discharge of air through the chimney and outlet shaft averages about 1200 cubic feet per head per hour, with a range from 700 to 1500 or 1600, according to the amount of fire, the warmth of the room, and the movement of the external air. The usual upward current through the outlet shafts at night, is from 3 to 5 feet per second. Sometimes the chimney and outlet a little counteract each other; a strong chimney draught may stop the current in the outlet shaft, but there is seldom any down-draught unless rain beats into the louvre and trickles down the inside of the shaft. The ventilation of barracks has been wonderfully improved by this plan, and the average carbonic acid ranges from ·7 to 1 per 1000 volumes, according to the rapidity of movement of the air.

The hospital system is precisely the same, except that the dimensions are nearly doubled.

Mediterranean Stations.—The same system is directed to be carried out whenever practicable at Malta and Gibraltar, only the size of the inlets and outlets are trebled; for example, there is 1 square inch of outlet for every 20 cubic feet of space instead of 60 as at home; great care is ordered to be taken to remove all outside obstacles to the movement of the wind.

The Tropics and India.—The same system in principle is now directed to be used in India. (See Barracks in Hot Climates for a fuller description.)

SECTION III.

ARTIFICIAL VENTILATION.

Artificial ventilation is accomplished in two ways; either the air is drawn out of a building or room (the method by extraction), or it is driven in, so as to force out the air already in the room (the method by propulsion).

Sub-Section I.—Ventilation by Extraction.

This is produced by the application of heat, so as to cause an upward current, or by the steam jet, or by a fan or screw, which draws out the air.

1. *Extraction by Heat.*—The common chimney is a well-known example of this. There is a constant current up the chimney, when the fire is burning, in proportion to the size of the fire and of the chimney. The usual current up a common sitting-room chimney, with a fair fire, is, as measured by an anemometer, from 3 to 6 feet per second. A very large fire will bring it up to 8 or 9 feet. The movement caused by a kitchen or furnace fire is, of course, greater than this. If the area of the section where the anemometer is placed be known, the discharge can be stated in cubic feet. In a room I have often examined, the area of the throat of the chimney is 1·5 square feet; there is no down draught, but an upward current, which, with a good fire, is 4 feet per

second. The discharge per second is then 6 cubic feet, or no less than 21,600 cubic feet per hour. The capacity of the room is 2000 cubic feet, so that a quantity equal to the total air in the room passes up the chimney nearly 11 times per hour. And yet, with this immense current, the room, when shut up with two or three persons, gets close. The reason is, that when the window is shut the fire is chiefly fed with air which enters below two doors, and which, flowing near the ground to the chimney, never properly diffuses through the room. The current near the ground moves from 1·6 to 2·6 feet per second, and chills the feet. A few feet above the ground no movement can be discovered. This is an example of great movement, but bad distribution of air, and, consequently, imperfect ventilation.

When the air enters in more equably, and is better distributed, the movement of air is from the inlets gently towards the fireplace; there is also said to be a movement, from above the fireplace, along the ceiling and down the walls, and then along the floor to the chimney. (Reid and Stewart, quoted by the Barrack Commissioners).

In the wards of Fort Pitt the current, with a good fire, is about $3\frac{1}{2}$ to $4\frac{1}{2}$ feet per second; and as the section area of the throat is ·5 square foot, the average discharge is about 7200 cubic feet per hour. In the barracks of Chatham, Dr Fyffe found the discharge by the chimney to be 9080 cubic feet per hour (average of six observations). In the barracks at Gravesend, Messrs Hewlett, Stanley, and Reed found the discharge to be 6120 cubic feet per hour (average of twenty observations). In the experiments of the Barrack Commissioners,* the chimney discharge ranged from 5300 to 16,000 cubic feet per hour, the mean of twenty-five experiments being 9904 cubic feet. Even in summer, without a fire, there is generally a good up-current, but it is difficult to state the amount. It may be then concluded that, with an ordinary fire, a chimney gives a discharge sufficient for four or five persons. If, then, more than this number of persons habitually live in the room, another outlet must be provided.

As the current up the chimney is so great when the fire is lighted, all other openings in a room, if not too many, become inlets; and, in this way, down-draughts of air may occur from tubes intended as outlets. There is no remedy for this; and if too much enters, the outlets must be more or less closed.

If the room be without openings, so that no air can reach the fire, air is drawn down the chimney, and a double current is established, by which the fire is fed. The down current coming in puffs is one cause of smoky chimneys, and may be at once cured by making an inlet.

The chimney and fire is a type of a number of other similar modes of ventilation by extraction.

The ventilation of mines is carried on by lighting a fire at the bottom of a shaft (the upcast or return shaft), or half a shaft, if there be only one. The air is drawn down the other or downcast or intake shaft, or half the shaft, and is then made to traverse the galleries of the mine, being directed this way or that by partitions. Double doors are used, so that there is no back or side rush of the air. The current passes through the upcast-shaft at the rate of from 8 to 10 feet per second; it flows through the main galleries at the rate of from 4 to 6 feet per second, or even more, and from 1000 to 2000 cubic feet per head per hour are supplied in good mines. In fire-damp mines much more than this is given, even as much as 6000 cubic feet per man per hour (Proceedings of Civil Engineers, vol. xii. p. 308). If the quantity of air be

* Report, 1861, p. 73.

reduced too low there is a serious diminution in the amount of work performed by the men. A horse is said to require 2466 cubic feet, and a light 59 cubic feet per hour. It may easily be conceived how skilfully the air must be directed, so as to traverse the most remote workings; in some mines a portion of air makes a circuit of from 30 to 40 miles before it can arrive at the up-cast-shaft. The size of the shafts in a colliery varies from 8 to 11 or 12 feet in diameter; the sectional area of a shaft of the former size would be 50 square feet. A current of 8 feet per second in the upcast shaft would give a discharge of 1,440,000 cubic feet per hour, which would give 720 men 2000 cubic feet per hour.

The sectional area and height of the extracting shaft, and of the tubes running into it, have been fixed by Péclet; the principle is to give to the shaft the greatest height which can be allowed, and the largest section which can be given,* without permitting the temperature of the contained air to fall so low as to be unable to overcome the resistance of the atmosphere at the top of the shaft, or the action of the winds.†

In large buildings the same plan is often used; a chimney (*cheminée d'appel* of the French) is heated by a fire at the bottom, and into the bottom of this shaft, close to the fire, run a number of tubes coming from the different rooms. Several French and English hospitals, and many other buildings, are ventilated in this way. Dr Reid for some years ventilated the Houses of Parliament in the same manner, and so powerful was his up-draught, that he could change the entire air in the building in a few minutes.

In dwelling-houses it has been proposed to have a central chimney, into which the chimneys of all the fires shall open, and to surround this with air-shafts connected with the tops of the rooms. It is supposed that, if other inlets exist, there will be a current both up the chimney and up the shaft running beside it.

In all these cases it requires that the workmanship shall be very exact, so that air shall not reach the extracting shaft except through the tubes.

It is now about a hundred and twenty years ago since Dr Mead brought before the Royal Society Mr Sutton's plan of ventilating ships on the same principle. Tubes running from the hold and various cabins joined together into one or two large tubes which opened into the ashpit beneath the cooking fires. If the doors of the ashpits were kept closed, the fires drew the air rapidly from all parts of the ship. Unfortunately, this plan never came into general use. The same plan was adopted by Dr Mapleton for the ventilation of the hospital ships employed in the last (1860) China War. The arrangement requires some watching to prevent careless cooks from allowing air to reach the fires in other ways.

On the same principle men-of-war are now being ventilated. The funnel and upper part of the boiler, and, as far as possible, all the steam apparatus, are enclosed in an iron casing, so that a space is left of some 3 or 4 feet between the casing and the funnel. When the fires are lighted, there is of course a strong current up this space, and to supply this the air is drawn down through all the hatchways towards the furnace doors. The temperature of the stoke-hole is reduced from 130° or 140° Fahr., to 60° and 70°; and the

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* De la Chaleur, 3d edit. 1861, t. iii. p. 66, *et seq.*

† The amount of the resistance given to the movement of air through the tubes leading to the shaft, and in the shaft itself, can be calculated from the formula given by Péclet at page 47 (t. iii.), but which it is unnecessary to introduce here. General Morin's observations show that the difference in the volumes of air passing through small openings is in the ratio of the square root of the area. The increased velocity through the smaller openings does not compensate for this great loss.

draught to the fires is so much more perfect, that more steam is obtained from the same amount of fuel. This plan, devised by Mr Baker, has been ingeniously applied by Admiral Fanshawe, late superintendent at Chatham dockyard, to the ventilation of every part of the ship where there are no water tight compartments. Edmond's plan combines with this the ventilation not only of the hold, but of the timbers of the ship.

Sometimes, instead of a fire at the bottom of the chimney, it is placed at the top; but this is a mistake, as there is a great loss of heat from the immediate escape of the heated air; the proper plan is to heat, as much as possible, the whole column of air in the chimney, which can only be done by placing the fire below.

Frequently, instead of, or in addition to a fire, heat is obtained in the shaft by means of hot water or steam pipes. This plan has long been in use in England,* and has since been introduced into France, and improved by M. Leon Duvoir. Warming, as well as ventilation, is accomplished by this method, which is in action at the Hospitals Lariboisière (in one-half) and Beaujon. It appears to be at once effectual and economical, though it has been sharply criticised by Grassi and Péclet. After a very long investigation into the merits of all rival plans, it was adopted by a French Commission for the warming and ventilation of the Palais de Justice at Paris, and has since been adopted in other public buildings, chiefly from the advocacy of General Morin.† The plan at the Hospital Lariboisière is simply this: an extracting shaft contains in the lower part a boiler, from which two spiral hot-water tubes run up to the requisite height in the shaft, and then, leaving it, pass downwards and enter the wards, in which they are coiled so as to form hot-water stoves, and then leaving the wards, they pass down and re-enter the boiler. There is a continual circulation of hot water, and in the shaft there is necessarily an upward current of air. But as the air is continually increasing in temperature towards the point of discharge, there is a loss of power, just as in the case of the fire being placed at the top instead of the bottom of the shaft. From the bottom of the wards air-conduits or tubes run into the extracting shaft, and thus the vitiated air is drawn out of the wards. The fresh air is admitted directly from the outside into the wards, and is warmed by being admitted through the coils of the hot-water tubes. In the summer the water is shut off from the water-stoves, but the temperature of the extracting shaft is still maintained.

It is certainly true that the ventilation by this plan is irregular;‡ and also, that in the Hospital Lariboisière, a much greater quantity of air passes through the extracting shaft than enters through the hot-water stoves.

In the summer, when there is ventilation without warming, the outflow of air from the wards varied from 84·4 cubic metres (2980 cubic feet) to 55·3 cubic metres (1952 cubic feet) per head per hour.§

In the winter, when there are both ventilation and warming, the outflow of air from the wards was 82·2 cubic metres, or 2902 cubic feet, per head per hour. Of that amount only 35 cubic metres (1235 cubic feet) entered by the water-stoves, the rest came in by doors and windows and other openings—an objectionable point, as the air might press in from the closets. Yet, in spite

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* It is in use at the Circuit Court-House in Glasgow, and in the Police Buildings at Edinburgh (Ritchie), and in many other buildings.

† Two excellent reports have been made by this Commission, of which General Morin is reporter. Their titles are given farther on. Much information is also given in General Morin's work on Ventilation. *Etudes sur la Ventilation*, Paris, 1863, 2 vols.

‡ Péclet- Traité de la Chaleur, 1861, t. iii. p. 267.

§ Grassi, *op. cit.* pp. 35-37.

of this, the temperature was maintained pretty well up to the limit fixed in the agreement, viz., 15° cent. or 59° Fahr.

Oil has been used in some cases instead of water.

Very frequently, instead of a fire or hot-water vessels, lighted gas is used to cause a current, and if the gas can be applied to other uses, such as lighting, cooking, or boiling water, the plan is an economical one.

In theatres the chandeliers have long been made use of for this purpose. M. Darcet proposed this for several of the old theatres in Paris, and the Commission* lately appointed to determine the mode of ventilation to be adopted in the Théatres Lyrique et du Cirque Impérial, have determined, after much consideration, that this plan is the best adapted for theatres. The details have, however, been somewhat modified from those devised by D'Arcet, and are too long to be here inserted, but they seem admirably adapted to distribute the entering air thoroughly, and to insure its discharge. The entering air is warmed by calorifères below the pit, and is then carried by flues to the front of the stage, and to the front of each tier of boxes, where they open at the floor. The outgoing air is drawn away by flues running from each box, and ending in a large central shaft surrounding the tube which carries off the products of the combustion of the central chandelier. But every gas-jet in the house, as well as the spare heat of the furnace, is made to contribute its share of movement. The amount which can be supplied in winter is 30 cubic metres (=1059 cubic feet) per head per hour. The burning of 20 cubic metres (706·2 cubic feet) of gas in one hour at the Opera Comique caused the discharge of 80,000 cubic metres of air (2,825,280 cubic feet). The temperature of the air was 9° cent. or 16° Fahr. above the external air. At the Vaudeville, 10 cubic metres (353 cubic feet) of gas was consumed per hour, and 15,523 cubic metres (548,210 cubic feet) passed through the chimney, so that 1 cubic foot of gas perfectly consumed caused the discharge of 1553 cubic feet of air. General Morin, from numerous experiments, found that 1 cubic metre of gas caused the discharge of 1000 cubic metres of air, or 1 cubic foot would cause the discharge of 1000 cubic feet of air.†

The advantages of extraction by heat, especially in the case of theatres and buildings where gas can be brought into play, are obvious.

There are some objections to extraction by the fire and hot-air shaft.

1. The inequality of the draught. It is almost impossible to keep the fire at a constant height. The same quantity of combustible material should be consumed in the same time every day, and the heat should be kept in by large masses of masonry. Still, with these precautions, the atmospheric influences, and changes in the quality of the combustibles, cannot be avoided.

2. The inequality of the movement from different rooms. From rooms nearest the shaft, and with the straightest connecting tubes, there may be a strong current, while from distant rooms the friction in the conduits is so great that little air may pass. The greatest care is therefore necessary in calculating the resistance, and in apportioning the area of the tubes to the resistance. This plan is, indeed, best adapted for compact buildings. Occasionally, if the friction be great, from too small size, or the angular arrangement of the conduits leading to the hot-shaft, there may be no movement at all in the conduits, but a down-current to feed the fire is established in the shaft itself—a state of things which was discovered by Dr Sanderson to exist in the ventilation of St Mary's Hospital in London.

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* Rapport de la Commission sur le Chauffage et la Ventilation du Théatre Lyrique et du Théatre du Cirque Impérial. Rapporteur le General Morin. Paris, 1861.

† Etudes sur la Vent. t. ii. p. 720.

3. The possibility of reflux of smoke, and perhaps of air, from the shaft to the rooms, is another objection of some weight.

4. The impossibility of properly controlling the places where fresh air enters. It will flow in from all sides, and possibly from places where it is impure, as from closets, &c.; air is so mobile that with every care it is difficult to bring it under complete control—it will always press in and out at the point of least resistance.

2. *Extraction by the Steam-jet.*—The moving agent here is the force of the steam-jet, which is allowed to pass into a chimney. The cone of steam sets in motion a body of air equal to 217 times its own bulk. Tubes passing from different rooms enter the chimney below the steam-jet, and the air is extracted from them by the strong upward current. This plan is best adapted for factories with spare steam. It was employed for some time in the ventilation of the House of Lords, but was finally abandoned.

3. *Extraction by a Fan or Screw.*—An extracting fan or Archimedean screw has been used to draw out the air. Several different kinds have been proposed by Messrs Combes, Letoret, Glepin, and Lloyd, and have been used in coal-mines in Belgium, and in some of the English mines. At the Abercarn mine, in South Wales, a fan is used of 13½ feet diameter; the vanes, eight in number, are 3½ feet wide by 3 feet long; at 60 revolutions per minute the velocity of the air is 782 linear feet per minute, and 45,000 cubic feet are extracted; the velocity at the circumference of the fan is 2545 feet per minute; the theoretical consumption of coal per hour is 17·4 lbs.*

Mr Van Hecke formerly used a fan for this purpose, in his system of ventilation of buildings, but he has found it better to abandon it, and to substitute a propelling fan. It was proposed by Mr Higgins to put in a chimney an Archimedean screw to be turned by the wind, and in this way it was thought a constant upward current would be caused. But the plan has little power, and is not now employed.

To both these methods of extraction some of the objections already noted apply, but extraction by the fan is, of course, more uniform.

Sub-Section II.—Ventilation by Propulsion.

This plan was proposed by Desaguiliers, in 1734,† when he invented a fan or wheel enclosed in a box. The air passed in at the centre of the fan, and was thrown by the revolving vanes into a conduit leading from the box. In some form or other this fan has been used ever since, and the conduits leading from it are now generally made large, so that the fan may move slowly, and deliver a large quantity of air at a low velocity. The fan, if small, is worked by hand; if larger, by horse, water, or steam power.

The fans are often made with six or eight rays, each carrying vanes at the end, which should be as close as possible to the enveloping box. In size, the length of the vanes should be more than half the length of the rays; the number of rays should augment with the diameter of the orifice of access.‡ (Péclet, p. 259.)

The amount of air delivered can be told by timing the speed of revolution of the extremities of the fan per second, or per minute; the effective velocity

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* Ure's Dictionary, 1860; Art. *Ventilation*, vol. iii. p. 961.

† Course of Experimental Philosophy, vol. ii. p. 561. The wheel was shown to the Royal Society in 1734.

‡ Péclet, De la Chaleur, 3d edition, 1860, t. i. pp. 259, 263. Numerous kinds of fans for propulsion and extraction are figured, and detailed accounts of construction and amount of work are given.

is equal to ¾ths of this, and this is the rate of movement of the air. If the section area of the conduit be known, the number of cubic feet discharged per second, minute, or hour can be at once calculated.

The power of this plan is very considerable. With a fan of 10 feet diameter, revolving sixty times per minute, the effective velocity is 1414 feet per minute. The rate of movement in the main channel should not be more than 4 feet per second; the conduits must gradually enlarge in calibre; and the movement, when the air is delivered into the rooms, should not be more than 1½ feet per second.

At the Hospital Lariboisière, in Paris, it is stated that 150 cubic metres (= 4296 cubic feet) have been delivered per head per hour, in the wards ventilated by the propelling fan of MM. Thomas et Laurens. It must, however, be remembered, that the later observations of General Morin have shown that much of the movement ascribed to the fan was really owing to natural ventilation.

This plan is very well adapted for those cases in which a large amount of air has to be suddenly supplied, as in crowded music halls and assembly rooms. St George's Hall at Liverpool is ventilated in this way. The air is taken from the basement; is washed by being drawn through a thin film of water thrown up by a fountain; is passed into calorifères (in the winter), where it can be moistened by a steam-jet, if the difference of the dry and wet bulb be more than four or six degrees, and is then propelled along the channels which distribute it to the hall. In summer, it is cooled in the conduits by the evaporation of water.

At the Hôpital Necker in Paris, and in many other places, the plan of Van Hecke is in use. A fan, worked by an engine, drives the air into small chambers in the basement, where it is warmed by cockle stoves, and then ascends into the rooms above, and passes out by outlet shafts constructed in the walls. The system is effective and economical, though it is only just to say that, the use of the fan excepted, it is precisely similar in principle to Sylvester's. Mr Phipson * states that 2·2 ℔. avoir. of coal will renew 86,065 cubic feet of air.

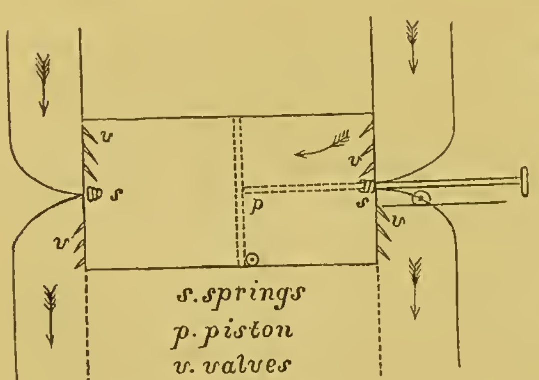

Fig. 20.

In America many of the larger establishments are ventilated on the same plan. The Utica Asylum (N.Y.) is ventilated † by a fan (14 feet diameter), worked by a 12-horse steam engine. The air taken at the basement enters a chamber filled with 80,000 feet of steam piping; and then, after being warmed, enters the wards at the floors, and rises to the ceiling, where it escapes through apertures.

In addition to the fan, other appliances have been used. Soon after Desaguiliers proposed the fan, Dr Hales employed large bellows for the same purpose, and they were used for some time on board some men-of-war, and in various buildings. They were worked by hand; and probably this, and their faulty construction, led to their being disused. Their use has been

* Notice of Dr Van Hecke's system, by W. W. Phipson. Reprint from "London Medical Review," 1862, p. 6.

† For this information I have to thank my friend, Dr C. W. Eddy.

revived, and their form modified and improved by Dr Arnott.* Dr Arnott has shown that Hales lost much power by forcing his air through small openings; and, by some ingenious alterations, has made an effective machine. It is a large box or cylinder, in which a piston works; openings are made at the ends of sufficient size; oiled silk hangs over the upper openings on the *inside*, and on the lower openings on the *outside* of the box. These covers, therefore, act as valves, and allow the air to pass in one direction only; as the piston moves, air is driven through the lower openings, on the side towards which the piston is moving, while fresh air enters at the same time through the upper openings at the opposite end. A pump of 6 feet long, 4 feet wide, made of deal boards, and fitted with a piston of wood, can be constructed in a few hours, and will deliver 96 cubic feet at every stroke, or 192 cubic feet at each double stroke of the piston. If ten strokes only are made per minute, nearly 2000 cubic feet of air are driven out in any direction.

Dr Arnott has also fitted up a gasometer pump, which was used in the York County Hospital for some time; it was worked by hydraulic pressure, and the expenditure of 60 gallons of water in an hour drove through the hospital 120,000 cubic feet of air. The air was warmed, if necessary, by water leaves.† This plan was in use for some time at the York Hospital, but was finally disused, probably because the apparatus, though excellent in principle, was not quite large enough.

The hydraulic air-pump, sometimes used in mines, is useful on a small scale; a circular vessel having above a hole closed by a valve (*a*) opening outwards, works up and down in a vessel nearly full of water, through which passes a tube into the mine shaft. This tube is closed above by a valve (*b*) opening upwards. When the cylinder moves down, air is forced out at (*a*); when it rises, air passes into it at (*b*), to be expelled through (*a*) at the next descent.‡

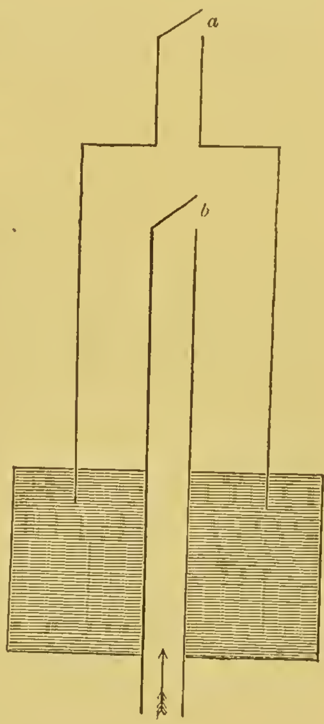

Fig. 21.

The punkah used in India is another mechanical agent with a similar though more imperfect action. When a punkah is pulled in a room open on all sides, it will force out a portion of air, the place of which will be at once supplied by air rushing in with greater or less rapidity from all points. If the punkah can be moistened in any way, its cooling effect is considerable. Captain Moorsom of the 52d Regiment, some years ago proposed an ingenious plan, which is given in the Indian Sanitary Report. A wheel turned by a bullock both moves the punkah, and elevates water, which then passes along the top of the punkah, and flows down it.

The advantages of ventilation by propulsion are its certainty, and the ease with which the amount thrown in can be altered. The stream of air can be

* "On the Smokeless Fireplace," by Neil Arnott, M.D., F.R.S., &c., 1855, p. 162; and in other publications. In the figure all the valves are shown open, but, during action, the top valves on one side, and the bottom on the other, are alternately open or closed.

† Water leaves (one of Dr Arnott's ingenious contrivances) are thin, flat boxes made of sheet copper, used instead of pipes; the boxes are set side by side, like the leaves of a book, about half an inch apart, and are connected by tubes, at the top and bottom, which pass to the boiler.

‡ Ure's Dictionary, 1860, vol. iii. p. 953.

taken from any point, and can, if necessary, be washed by passing through a thin film of water, or through a thin screen of moistened cotton, and can be warmed or cooled at pleasure to any degree. In fact, the engineer can introduce into this operation the precision of modern science.

The disadvantages are the great cost, the chances of the engine breaking down, and some difficulties in distribution. If the air enter through small openings, at a high velocity, it will make its way to the outlets without mixing. The method requires, therefore, great attention in detail.

SECTION IV.

RELATIVE VALUE OF NATURAL AND ARTIFICIAL VENTILATION.

Circumstances differ so widely, that it is impossible to select one system in preference to all others. In temperate climates, in most cases, especially for dwelling-houses, barracks, and hospitals, natural ventilation, with such powers of extraction as can be got by utilising the sources of warming and lighting, is the best. Who, in fact, would not attempt to make use of these vast powers of nature, which are ever ready to serve us? Incessant movement of the air is a law of nature. We have only to allow the air in our cities and dwellings to take share in this constant change, and ventilation will go on uninterruptedly without our care.

In some circumstances, however, as in the tropics, with a stagnant and warm air; and in temperate climates in certain buildings, where there are a great number of small rooms, or where sudden assemblages of people take place, mechanical ventilation must be used. So much may be said both for the system of extraction and propulsion under certain circumstances, that I think it is impossible to give an abstract preference to one over the other. This is evident, indeed, from the fact, that quite contrary opinions have been arrived at by equally competent men. Péclet, whose great authority no one can doubt, says (De la Chaleur, t. iii. p. 63), "Mechanical ventilation has then an immense advantage over the ventilation of an extracting chimney" (*cheminée d'appel*); and Grassi, from a comparison of the two plans at the Lariboisière Hospital, unequivocally condemned the system of extraction as arranged by Duvoir. Yet, lately, General Morin, after a fresh inquiry into the whole subject, has as decidedly pronounced the system of propulsion to be everywhere inferior to that by extraction. He has also condemned the plan of Van Hecke, which previously had been praised by Pettenkofer. In fact, it is evident that the special conditions of the case must determine the choice, and we must look more to the amount of air, and the method of distribution, than to the actual source of the moving power. But in either case the greatest engineering skill is necessary in the arrangement of tubes, the supply of fresh air, &c. The danger of contamination of air as it passes through long tubes, and the immense friction it meets with, must not be overlooked. For hospitals I cannot but believe natural ventilation is the proper plan. (See Hospitals.) The cost of the various plans will depend entirely on circumstances; the nature of the building; the price of materials, coal, &c. On the whole, the plans of ventilating and warming by hot-water pipes, and Van Hecke's plan, are cheaper than the method by propulsion by means of a large fan; but the latter gives us a method which is more under engineering control, and is better adapted for hot climates when it is desired to cool the air. (See Barracks in Hot Climates.)

CHAPTER IV.

EXAMINATION OF AIR AND OF THE SUFFICIENCY OF VENTILATION.

The sufficiency of ventilation should be examined :—

1*st*, By determining the amount of cubic space assigned to each person, and the amount of movement of the air, or, in other words, the number of cubic feet of fresh air which each person receives per hour.

2*d*, By examining the air by the senses, and by chemical and mechanical methods, so as to determine the presence, and, if possible, the amounts of suspended matters, organic vapour, carbonic acid, sulphuretted hydrogen, and watery vapour.

SECTION I.

MEASUREMENT OF CUBIC SPACE.*

The three dimensions of length, breadth, and height are simply multiplied into each other. If a room is square or oblong, with a flat ceiling, there is, of course, no difficulty in doing this, but frequently rooms are of irregular form, with angles, projections, half-circles, or segments of circles. In such cases the rules for the measurement of the area of circles, segments, triangles, &c., must be used. By means of these, and by dividing the room into several parts, as it were, so as to measure first one and then another, no difficulty will be felt. After the room has been measured, recesses containing air should be measured and added to the amount of cubic space, and on the other hand, solid projections, and solid masses of furniture, cupboards, &c., must be measured, and their cubic contents (which take the place of air), deducted from the cubic space already measured. The bedding also occupies a certain amount of space; a soldier's hospital mattress, pillow, three blankets, one coverlet, and two sheets, will occupy about 10 cubic feet. It is seldom necessary to make any deduction for tables, chairs, and iron bedsteads, or small boxes; it is a refinement to do this, or to reduce the temperature of the air to standard temperature, as is sometimes done.

A deduction must be made, however, for the bodies of persons living in the room; a man of average size takes the place of about $2\frac{1}{2}$ to 4 cubic feet of air (say 3 for the average).

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* The following are some useful measures :—

1 cubic foot,	=	1728 cubic inches.
„ „	=	28·31 French litres.
1 cubic metre (French),	=	35·31658 cubic feet (English).
1 litre (French),	=	0·035316 cubic feet.
1 litre,	=	61·027 cubic inches.
1 cubic centimetre,	=	0·06103 cubic inches.

The Prussian foot is equal to 12·357 inches, or 1·0298 English feet, and the cubic foot Prussian is equal to 1·092 cubic feet English, or almost 1-10th more. The Prussian square foot is equal to 152·7 square English inches, or 1·0605 English square feet. One English square foot is equal to ·9429 Prussian square feet.

In linear measurement, it is always convenient to measure in feet and decimals of a foot, and not in feet and inches. If square inches are measured, they may be turned into square feet by multiplying by ·007.

RULES—*Area or Superficies.*

Area of circle, ... $= D^2 \times \cdot 7854.$

" " . . . . . $= C^2 \times \cdot 08.$

Circumference of circle, . . . $= D \times 3 \cdot 1416.$

Diameter of circle, ... $= C \div 3 \cdot 1416.$

Area of ellipse, ... = Multiply the product of the two diameters by ·7854.

Circumference of ellipse, . . . = Half sum of the two diameters by 3·1416.

Area of rectangle, ... = Multiply two sides.

Area of parallelogram, . . . = Multiply a side by its width on the square.

Area of Trapezium, ... = Multiply ½ sum of the two perpendiculars by the diagonal on which they fall; or

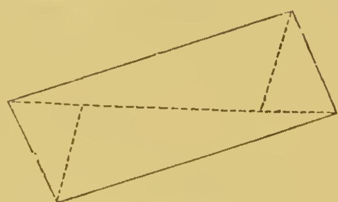

Fig. 22.

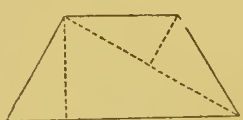

Fig. 23.

Divide into two triangles in the most convenient manner, calculate the areas, and take the sum.

Area of trapezoid, ... = Take ½ the sum of the parallel sides and multiply by the distance bebetween them.

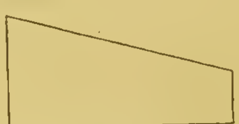

Fig. 24.

Area of triangle, ... = Base × ½ height, or Height × ½ base.

Fig. 25.

Area of segment of circle, . . . = To ⅔ of product of chord and height add the cube of the height divided by twice the chord

$$(Ch \times H \div \tfrac{2}{3}) + \frac{H^3}{2\,Ch}$$

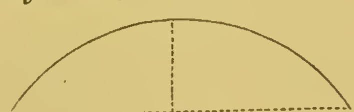

Fig. 26.

or calculate by equidistant ordinates. Divide the base into any number of even equidistant parts, and measure the height of each ordinate.

Take sum of first and last ordinates,	=	A
,, all the even ordinates,	=	B
,, all the uneven ordinates, (except the first and last).	=	C

Add together, A
4B
2C

and divide by 3. Multiply product by the common distance between the ordinates.

Cubic Capacity of a Cube.—Multiply the three dimensions; length breadth, and height.

Cubic Capacity of a Cone or Pyramid.—Area of base × $\frac{1}{3}$ height.

Cubic Capacity of a Cylinder.—Area of base × height.

Cubic Capacity of a Parallelopiped.—Multiply area of one side by the perpendicular let fall on it.

Cubic Capacity of a Dome.—Two-thirds of the product of the area of the base multiplied by the height (area of base × height × $\frac{2}{3}$).

Cubic Capacity of a Sphere.—$D^3 \times \cdot 5236$.

The cubic capacity of a bell-tent may be taken as that of a cone.

The cubic capacity of an hospital marquee must be got by dividing the marquee into several parts—1*st*, into body; and 2*d*, roof:—

1. Body, as a solid rectangle, with a half cylinder at each end.
2. Roof, solid triangle, and two half cones.

The total number of cubic feet, with additions and deductions all made, must then be divided by the number of persons living in the room; the result is the cubic space per head.

SECTION II.

MOVEMENT OF AIR IN THE ROOM.

The direction of movement must first be determined, and then its rate.

1. DIRECTION OF MOVEMENT.

First enumerate the various openings in the room—doors, windows, chimney, special openings, and tubes—and consider which is likely to be the direction of movement, and whether there is a possibility of thorough movement of the air. Then, if it is not necessary to consider further any movement through open doors or windows, close all these, and examine the movement through the other openings. This is best done by smoke disengaged from smouldering cotton-velvet, and less perfectly by small balloons, light pieces of paper, feathers, &c. The flame of a candle, which is often used, is only moved by strong currents. It may be generally taken for granted that one-half the openings in a room will admit fresh air, and half will be outlets. But this is not invariable, as a strong outlet, like a chimney, may draw air through an inlet of far greater area than itself, or may draw it through a much smaller area, with an increased rapidity.

2. RATE OF MOVEMENT.

The direction being known, it is only necessary to measure the discharge through the outlets, as a corresponding quantity of fresh air must enter.

By the Anemometer.—This is best done by an anemometer, of which there

are several in the market. The one commonly used is that invented by Combes in 1838; four little sails, driven by the moving air, turn an axis with an endless screw, which itself turns some small toothed wheels, which indicate the number of revolutions of the axis, and consequently the space traversed by the sails in a given time, say one minute. M. Neuman, of Paris, has modified this anemometer by omitting most of the wheels, and introducing a delicate watchmaker's spring, which opposes the force of the wind, and when it equals it, brings the sails to a stand-still. By a careful graduation (which must be done for each instrument), the rate per second is determined, and is indicated by a small dial and index.

Mr Casella, of Hatton Garden, has, at my suggestion, modified and improved this instrument, and has adapted it to English measures. A very beautiful instrument is thus available at a comparatively low price, by which the movement of air can be measured very readily.

The anemometer is thus used:—Being set at the zero point, it is placed in the current of air; if it is placed in a tube or shaft, it should be put well in, but not quite in the centre, as the central velocity is always greater than that of the side; a point about two-fifths from the sides of the tube will give the mean velocity. As soon as the sails stop rotating, or at a given time if Casella's instrument be used, the instrument is removed, and the movement per second or per minute, or in the time noted, is given by the dial. If this linear discharge is multiplied by the section-area of the tube or opening (expressed in feet or decimals of a foot), the cubic discharge is obtained. If the current varies in intensity, the movement should be taken several times, and the mean calculated; and if the tube is so small that the sails approach closely to the circumference, the results cannot be depended on. If placed at the mouth of a tube, it often indicates a much feebler current than really exists in the tube.

The cubic discharge per second being known, the amount per hour is got by multiplying by 3600, and this, divided by the number of men in the room, gives the discharge per head for that particular aperture.

An anemometer on a larger scale is fixed in some of the large outlets of the Paris hospitals, showing the movement at every moment by means of an index and dial.*

By the Manometer.—Dr Sanderson has made an ingenious alteration of a manometer described by Péclet, which can also be employed to measure the pressure, and by calculation the velocity, of the air. The current of air is allowed to impinge on a surface of water, and the height to which the water is driven up a tube of known inclination and size gives at once a measure of force. But, as necessitating a little calculation, this instrument is less useful than the anemometer, though it is adapted for cases where the anemometer cannot be used, as it may be connected by a long tube with a distant room, and probably would be well fitted to measure constantly the velocity in an extraction shaft.

By Calculation.—Supposing the external air is tranquil, and that the only cause of movement is the unequal weights of the external colder and the internal warmer air, the amount of discharge may be approximately obtained by the law of Montgolfier described in the chapter on VENTILATION. There is a fallacy, however, as the amount of friction can never be precisely known. Still, as an approximation, and in the absence of an anemometer, the rule is useful; and I have therefore calculated a table as follows.

On testing this table, however, by the anemometer, I have found it give too much when the tubes are long, on account of the great friction, and I

* Péclet—De la Chaleur, t. i. p. 171, where the description will be found.

would therefore advise the further deduction of $\frac{1}{6}$th when the shaft or tube is long, and is at the same time of small diameter. If the tube has many angles, or is greatly curved, this table is too imperfect to be used.

TABLE *to show the Discharge of Air in linear feet per minute. Calculated from Montgolfier's formula; the expansion of air being taken as* 0·002 *for each degree Fahrenheit, and one-fourth being deducted for friction. (Round numbers have been taken.)*

Height of column.	Difference between Internal and External Temperature.																						
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	30
10	88	102	114	125	135	144	153	161	169	176	183	190	197	204	210	216	222	228	233	239	244	249	254	279
11	92	107	119	131	141	151	160	169	177	185	192	200	207	213	220	226	233	239	245	250	256	261	267	292
12	96	111	125	136	147	158	167	176	185	193	201	209	216	223	230	237	243	249	255	261	267	273	279	305
13	100	116	130	140	153	164	174	183	192	201	209	217	225	232	239	246	253	259	266	272	278	284	290	318
14	104	120	135	147	159	170	181	190	200	209	217	225	233	241	248	255	262	269	276	282	289	295	301	330
15	108	125	139	153	165	176	187	197	207	216	225	233	241	249	257	264	272	279	286	292	299	305	312	341
16	111	129	144	158	170	182	193	204	213	223	232	241	249	257	265	273	281	288	295	302	309	315	322	353
17	115	133	148	162	176	188	199	210	220	230	239	248	257	265	274	282	289	297	304	311	318	325	332	363
18	118	136	153	167	181	193	205	216	226	237	246	255	264	273	282	290	298	305	313	320	327	335	342	374
19	121	140	157	172	186	198	210	222	233	243	253	262	272	281	289	298	306	314	321	329	336	344	351	384
20	125	144	161	176	190	204	216	228	239	249	259	269	279	288	297	305	314	322	330	338	345	353	360	394
21	128	147	165	181	195	209	221	233	245	255	266	276	286	295	304	313	321	330	338	346	354	361	369	404
22	131	151	169	185	200	214	226	239	250	261	272	282	292	302	311	320	329	338	346	354	362	370	378	414
23	134	154	173	189	204	218	232	244	256	267	278	289	299	309	318	327	336	345	354	362	370	378	386	423
24	136	158	176	193	209	223	237	249	261	273	284	295	305	315	325	335	344	353	361	370	378	386	394	432
25	139	161	180	197	213	227	241	254	267	279	290	301	312	322	332	342	351	360	369	378	386	394	402	441
26	142	164	183	201	217	232	246	259	272	284	296	307	318	328	338	348	358	367	376	385	394	402	410	450
27	145	167	187	205	221	237	251	264	277	290	302	313	324	335	345	355	365	374	383	392	401	410	418	458
28	147	170	190	207	225	241	255	269	282	295	307	319	330	341	351	361	371	381	390	399	408	417	426	467
29	150	173	194	212	229	245	260	274	287	300	312	324	335	347	357	368	378	388	397	407	416	425	433	475
30	153	176	197	216	233	249	264	279	292	305	318	330	341	353	363	374	384	394	404	414	423	432	441	483
31	155	179	200	219	237	253	269	283	297	310	323	335	347	358	369	380	391	401	411	420	430	439	448	491
32	158	182	204	223	241	257	273	288	302	315	328	341	353	364	375	386	397	407	417	427	437	446	455	499
33	160	185	207	226	245	261	277	292	307	320	333	346	358	370	381	392	403	414	424	434	443	453	462	506
34	162	188	210	230	248	265	282	297	311	325	338	351	363	375	387	398	409	420	430	440	450	460	469	514
35	165	190	213	233	252	269	286	301	316	330	343	356	369	381	393	404	415	426	436	447	457	467	476	522
36	167	193	216	236	255	273	290	305	320	334	348	361	374	386	398	410	421	432	442	453	463	473	483	529
37	170	196	219	240	259	277	294	310	325	339	353	366	379	392	404	415	427	438	448	459	470	480	490	536
38	172	198	222	243	262	281	298	314	329	344	358	371	384	397	409	421	432	444	454	465	476	486	496	543
39	174	201	225	246	266	284	302	318	333	348	362	376	389	402	414	426	438	450	461	471	482	492	503	551
40	176	204	228	249	269	288	305	322	338	353	367	381	394	407	420	432	444	455	467	477	488	499	509	558
45	187	216	241	264	286	305	324	341	358	374	389	404	418	432	445	458	471	483	495	506	518	529	540	591
50	197	228	254	279	301	322	341	360	377	394	401	426	441	455	469	483	496	509	522	534	546	558	569	623
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	30

To use the table, determine the height of the warm column of air from the point of entrance to the point of discharge. Ascertain the difference between its temperature and that of the external air. Take out number from table, and multiply by the section-area of the discharge-tube or opening, in foot or decimals of a foot. The result is the discharge in cubic feet per minute, multiply by 60—result, discharge per hour. *Example.*—Height of column, 32 feet; difference of temperature between internal and external air, 17 deg. Looking in the table, we find opposite to 32 and under 17, 375 feet. That would be for an area of 1 square foot.

But supposing our air opening to be only $\frac{3}{4}$ of a foot, we must multiply 375 by $\frac{3}{4}$ or 0·75 of a foot.

$$\left\{\begin{array}{r} 375 \\ \cdot 75 \\ \hline 1875 \\ 2625 \\ \hline 281{\cdot}25 \end{array}\right\}$$

Therefore we get 281 feet (per minute), multiplied by 60 = 16,860 feet per hour.

If the movement of the external air influences the movement in the room, as when the wind blows through openings, calculation is useless, and the anemometer only can be depended on.

SECTION III.

EXAMINATION OF THE AIR.

1. BY THE SENSES.

Many impurities are quite imperceptible to smell, but it so happens that animal organic matters, whether arising in respiration or in disease, have, for the most part, a peculiar fœtid smell, which is very perceptible to those trained to observe it when they enter a room from the open air. This is, in fact, a most delicate, as well as a ready way of detecting such fœtid impurities, and, with a little trouble, the sense of smell may be cultivated to the point of extreme acuteness. Only, it must be remembered, that in a short time the impression is lost, and is not at once regained even in the open air.

As the evidence of the senses, however practically useful, is always liable to be challenged, a more thorough examination of the air must in many cases be made.

2. MICROSCOPICAL AND CHEMICAL EXAMINATION.

The points which can be examined at the present day are—

1. The existence and nature of suspended matters.
2. The action of organic matter on potassium permanganate.
3. The amount of carbonic acid.
4. The amount of watery vapour.
5. The presence of ammonia and sulphuretted hydrogen.

1. *Suspended Substances.*—The aeroscope invented by Pouchet offers an easy mode of examining the suspended matters in air. Air is drawn, by means of an aspirator, through a funnel, the end of which is brought to a fine point, immediately below which is placed a slip of glass moistened with glycerine. The end of the funnel and glass are enclosed in a little air-tight chamber, from which a small glass tube passes up, and is connected by means of india-rubber tubing with an aspirator. As the water runs out the air can only pass into the aspirator through the funnel, and, as it does so, any solid particles carried down with the current impinge on and are arrested by the glycerine, and can be afterwards examined by the microscope. An aspirator can be made for a few shillings; a square tin vessel with a tap below, and a small opening above to receive the india-rubber tube, is all that is necessary. The capacity of the aspirator is told by filling it with water, and then letting the water run out into a measured vessel. If an ounce measure is used, the number of ounces, multiplied by 1·733, will give the capacity in cubic inches, and dividing by 1728, will bring the same into cubic feet.

A still better plan is by drawing the air through pure boiled water. All the solid particles are retained at the bottom of the vessel, and can be afterwards microscopically examined.

2. *Organic Matter.*—This can be examined as follows. A solution of potassium permanganate which has been graduated with oxalic acid—in the manner described in the chapter on the mode of determining the organic matter in water—is taken, and diluted to such an extent as that 100 C.C. shall contain 0·0001 grammes of permanganate, or any known small quantity which gives a perceptible colour to the water; the air is drawn through this slowly by an aspirator; the number of times the aspirator is emptied and filled being known, the number of cubic feet drawn through the water is also known. The process is over when the colour has disappeared, or the excess of per-

manganate may be determined, as given in the chapter on WATER (footnote, p. 39). As the quantitative relations of the organic matter of air and potassium permanganate are not yet accurately known, the result should be simply noted, that 0·0001 grammes of permanganate required so many cubic feet of air for complete decolorisation. The fallacy of this process is that tarry matters derived from combustion, sulphuretted hydrogen, sulphurous acid, and other matters, act on the permanganate; however, no other process has been yet proposed which is equal to it.

The air may also be drawn through tubes cooled by a freezing mixture; the water of the air and the organic matter condense together; this is a very good plan.

3. *Carbonic Acid.*—For our purpose the method proposed by Pettenkofer is the best. A glass vessel is taken capable of holding from half a gallon to $1\frac{1}{2}$ gallon. The capacity is determined by filling it with water, and by measuring the contents by means of a litre or ounce measure (1 oz. = 1·733 cubic inches). The vessel is thoroughly dried, and is then filled with the air to be examined, which is most readily done by pumping in the air with a bellows. When this is done 60 C.C. of clear lime or baryta water are put in, and the mouth is closed with an india-rubber cap. The vessel is agitated, so that the lime water may run over the sides, and then is left to stand for not less than six or eight hours, and not more than twenty-four hours. The carbonic acid is absorbed by the lime or baryta water, and consequently the causticity of these fluids is, *pro tanto*, lessened. If the causticity of the lime or baryta is known before and after it has been placed in the vessel, the difference will give the amount of lime or baryta which has become united with carbonic acid.

The causticity of lime is determined by means of a solution of crystallised oxalic acid. If 2·25 grammes of crystallised $\overline{O}$ ($\overline{O}$ + 3Aq) are dissolved in 1 litre of water, 1 C.C. will exactly neutralise 1 milligramme (·001 gramme) of lime; 30 C.C. of lime water are taken, and exactly neutralised; good turmeric paper is the best plan for determining the exact point of neutralisation, and the margin of the drop gives the most delicate indication. The amount of lime in the 30 C.C. is then equal to the number of C.C. of oxalic acid used; it is always somewhere between 34 and 39 milligrammes.

After the lime has absorbed the carbonic acid of the air in the vessel, 30 C.C. of the solution are taken out, and neutralised by oxalic acid; the difference between the first and second operations is doubled (to account for the 30 C.C. left in the vessel, 60 being always put in to allow 30 to be taken out, and also to allow a repetition of the experiment if necessary). This gives the amount of lime which has combined with carbonic acid, and the amount of the latter is known by simply calculating according to the atomic weights, and then converting weight into measure. This is done in one sum by multiplying by ·39521. The capacity of the vessel being known, the amount of CO_2 is calculated for 1000 volumes by simple rule of three. From the capacity 60 C.C. must be deducted, to account for the lime-water put in.

A correction must be also made for temperature. The standard temperature being 62°, if the air of the room which is examined be below this, the quantity of air actually acted upon will necessarily be greater from condensation than would have been the case had the air been warmer; and conversely, if the temperature be higher than 62°, a less quantity of air must have been operated on than would have been the case had the air been at the lower temperature of 62°.

This error is corrected by multiplying ·0020361 (the co-efficient of expansion of air for 1° Fahr.) by the difference between 62° and the observed tem-

perature, and then by the capacity of the vessel, and adding the product to the capacity if the temperature be below 62°, and subtracting it if it be above 62°.

A correction for pressure is not necessary, unless the place of observation be much removed from sea-level; in that case, the barometer must be observed, and a rule of three stated.

$$\text{As } \left.\begin{array}{c}\text{standard height}\\ \text{of bar } (=30 \text{ in.})\end{array}\right\} : \left\{\begin{array}{c}\text{observed height}\\ \text{of bar}\end{array}\right\} : : \text{ capacity } : x.$$

Baryta water may be used instead of lime water, but it must be free from traces of potash or soda.

4. *Watery Vapour.*—The hygrometric condition of the air is known in various ways, especially by the dry and wet bulbs, as explained in the chapter on METEOROLOGY. The hair hygrometer is a very useful instrument for this purpose, as it marks the degree of humidity much more quickly than the dry and wet bulbs.

5. *Ammonia* is determined by Nessler's test (see chapter on WATER); a known quantity of air is drawn through by the aspirator, and the weight of the precipitate determined; then by rule of three:

$$\text{As } 559 : 17 : : \text{ weight of process } : x.$$

The mere presence of ammonia may be also detected by logwood paper. Tincture of logwood is evaporated to dryness, and the residue dissolved in ether. Strips of filtering paper are soaked in it; ammonia gives a brownish colour. Sulphuretted hydrogen is best detected by exposing strips of blotting paper dipped in a solution of subacetate of lead. Ammonium sulphide is detected by paper dipped in the solution of nitroprusside of sodium.

SECTION IV.

SCHEME FOR THE APPLICATION OF THE FOREGOING RULES.

The ventilation of a certain room being about to be examined, enter it after being at least fifteen minutes in the open air, and notice if there is any smell. Measure the cubic space, then consider the possible sources of entrance and exit of air; if there are only doors and windows, notice the distance between them, how they open, on what external place they open; whether there is free passage of air from side to side; whether it is likely the air will be properly distributed. On all these points an opinion is soon arrived at. If there are other openings, measure them all carefully, so as to get their superficies; the chimney must be measured at its throat or smallest part. Determine then the direction of movement of air through these openings by smoke, noting the apparent rapidity. The doors and windows should be closed. When the inlets have been discovered, consider whether the air is drawn from a pure external source, and whether there is proper distribution in the room. Then measure the amount of movement in the outlets with an anemometer, or calculate by the table if it seems safe to do so.

If the ventilation of the room is influenced by the wind, the horizontal movement of the external air should be determined by Robinson's anemometer, which is now supplied to many military stations.

Then proceed to the microscopical and chemical examination, if this is considered desirable, as it will frequently be. In determining the carbonic acid, put out all the lights or have only sufficient for working purposes; allow no smoking, and have no person in the room but those who are sleeping there.

CHAPTER V.

FOOD.

SECTION I.

GENERAL PRINCIPLES OF DIET.

A FOOD is either a substance with a store of potential or latent energy, which is capable of being manifested in the body under the form of heat, electricity, mechanical movement, formative power (if such a term may be used), &c., and which manifestations serve the purposes of healthy life,* or it is a substance which aids or permits the manifestation and application of this energy. Under the first head come all the substances capable of oxidation (or deoxidation, or splitting, if it be hereafter proved that energy is manifested or transformed during such alterations); and under the second, the substances which, though not oxidisable, play an essential part in preparing the conditions for chemical changes, such as water and some salts.† Neither class, *per se*, is capable of the manifestation of energy, and therefore the title of food is strictly applicable only when both classes are present. Indeed, it may be said that the full powers as food, even of the first class, are only manifested when certain different kinds of aliments which make up the class exist together. In the case of man, albumen or sugar, which are both foods when other substances are present, will not alone maintain healthy nutrition, and therefore if given singly they are alimentary principles, with a power of acting as food which cannot be manifested. There must, therefore, be a combination of the so-called foods to maintain perfect nutrition. The enumeration and classification of the foods or aliments necessary to maintain human life in its most perfect state has been usually based on the deduction of Prout, that milk contains all the necessary aliments, and in the best form. The substances in milk are—1st, the nitrogenous matters, viz., the casein principally, and in smaller quantities, albumen, lacto-protein, and perhaps other albuminous bodies; 2d, the fat and oil; 3d, sugar in the form of lactin; 4th, water and salts, the latter being especially combinations of magnesium, calcium, potassium, sodium, and iron, with chlorine, phosphoric acid, and in smaller quantities sulphuric acid.

In addition to their occurrence in milk, which is admitted to be a perfect food for the young, this enumeration of aliments appears to be justified by two considerations. First, that the different members of each class, *inter se*, have a remarkably similar composition, while there are broad lines of physical

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* The addition that the manifestation of energy in the body serves the purposes of healthy nutrition is necessary to distinguish the actions of food from those of medicines or poisons, which only serve healthy nutrition indirectly by acting on the processes of unhealthy nutrition.

† These two classes have been called the "force-generators" and the "force-regulators." (See for a very able discussion, Dr M. Foster's article "Nutrition," in Watt's Chemistry, 1866). The term "regulator" does not seem to me a very good one, at least it is rather an assumption. Phosphate of lime is perhaps an essential element in cell growth, but it does not regulate the formation.

and chemical demarcation between the classes; and secondly, that the different classes appear to serve different purposes in nutrition, and are all necessary for perfect health. The first point is obvious enough.

The nitrogenous aliments are blood-fibrine, muscle-fibrine or syntonin, myosin, vegetable fibrine, albumen in its various forms, casein (in its animal and vegetable forms), and globulin. Their composition, &c., is remarkably uniform; they contain between 15·4 and 16·5 per cent. of nitrogen, and may be conveniently distinguished by the common term of albuminates. They can replace each other in nutrition. There are some other nitrogenous bodies, such as gelatine and chondrin, and the substances classed under keratin or elastin, which, though approaching in chemical characters to the other substances, are not their nutritive equals, but still what nutritive power they have takes apparently the same direction.

The second class consists of the various animal and vegetable fats, wax, &c., the composition of which is very uniform, and the chief nutritive differences of which depend on physical conditions of form or aggregation, which cause some fats, when acted upon by the alimentary fluids, to be more easily absorbed than others.

The group of the starchy and saccharine substances (the carbo-hydrates), or of their allies or derivatives (dextrin, pectin), is equally well characterised by chemical resemblances, *inter se*, and differences from the other groups. The several dietetic starches, sugars, including lactin, cellulose (whose want of nutritive power is dependent on form and aggregation, and which requires for digestion a more elaborate apparatus than some animals possess), and the various derivatives of the starches, are all closely allied. There has been some doubt whether pectin should be classed chemically with the sugar and starch group, as the oxygen and hydrogen are not in the proportions to form water, but this is perhaps no objection to its association in a dietetic classification.

The fourth class, consisting of the salts already noted and of water, need no comment.

The physiological evidence that these classes of aliments serve different purposes in nutrition is not so complete as that of their chemical differences.

Few will doubt, I presume, that a broad distinction must be drawn between the nitrogenous and non-nitrogenous substances. Late researches, which have much modified our opinion of the direction in which the latent force of the dietetic principles may be manifested (as heat, or electricity, or mechanical movement), and of the mode in which the nitrogenous substances in particular, aid or restrain this transformation, do not, it appears to me, impeach the proposition that the presence of nitrogen in an organised structure, and its participation in the action going on there, is a necessary condition for the manifestation of any force, or any chemical change. Whether, when force is manifested, the nitrogenous framework of any nitrogenous structure is a mere stage on which other actors play, or whether it is used up and destroyed, or is, on the other hand, built up or and renovated during action, is, as far as classification of food is concerned, a matter of no consequence.

The following considerations seem to prove the necessary participation of the nitrogenous structures in manifestations of force.* Every structure in the body in which any form of force is manifested (heat, mechanical motion, chemical or electrical action, &c.) is nitrogenous. The nerves, the muscles, the gland cells, the floating cells in the various liquids, the semen and the ovarian cells, are all nitrogenous. Even the non-cellular liquids passing out

* I use the term force in its common acceptation, to include potential force and active energy power latent and power manifested.

into the alimentary canal at various points, which have so great an action in preparing the food in different ways, are not only nitrogenous, but the constancy of this implies the necessity of the nitrogen, in order that these actions shall be performed; and the same constancy of the presence of nitrogen, when function is performed, is apparently traceable through the whole world. Surely such constancy proves necessity. Then, if the nitrogen be cut off from the body, the various functions languish. This does not occur at once, for every body contains a store of nitrogen, but it is at length inevitable. Again, if it is wished to increase the manifestation of the energies of the various organs, more nitrogen must be supplied. All these points are matters of direct evidence, and are independent of theory. But they are supported to some extent by physiological evidence. Thus, the experiments of Pettenkofer and Voit show that the nitrogenous substances composing the textures of the body determine the absorption of oxygen.* The condensation of the oxygen from the atmosphere, its conversion into its active condition (ozone), and its application to oxidation, are according to their experiments entirely under the control of the nitrogenous tissues (fixed and floating), and are apparently proportional to their size and vigour.† In other words, without the participation of the nitrogenous bodies, no oxidation and no manifestation of force is possible. If I rightly interpret the experiments, they show that the absorption of oxygen by the lungs (blood-composition, and physical conditions of pressure, &c., remaining constant), is dependent on its disposal in the body, and that this disposal is in direct relation with the absolute and relative amount and action of the nitrogenous structures. It is not, as we formerly thought, that the appearance of mechanical motion or of electricity is owing solely to a transformation of nitrogenous tissue. Mechanical motion, electricity, or heat may probably be owing to oxidation of fat or of starch, or of nitrogenous substance; but whatever be the final source, the direction is given by the nitrogenous structures. The experiments on bodily exercise, which have seemed to some to overthrow all our old ideas of diet, do not really do so; they only better define, it seems to me, the limits within which the nitrogenous bodies act, and leave the cardinal rules of diet much as before.

I believe, then, that Liebig was fully justified in drawing this broad line between the nitrogenous and the non-nitrogenous substances, and in attaching so much importance to the former class.

The next point is not quite so clear. Are the non-nitrogenous bodies, the fats and the starches, to be again broadly separated into two groups, which cannot replace each other; or, are these nutritively convertible? And to this question another may be added, Are there not chemical changes going on in the body which may convert a nitrogenous substance into a non-nitrogenous, so that the nitrogenous substance may play two parts—first, of the organic framework, *i.e.*, of the regulator of oxidation and of transformation of force; and second, of the non-nitrogenous substance which is oxidised and transformed, and if so, may not an albuminate replace fat and starch under certain conditions?

The experiments of Edward Smith, Fick, and Wislicenus, Haughton, and others, on muscular action, seem to prove that we must look for the main source of energy which is apparent during muscular action in the oxidation

* Zeitsch. für Biologie, band ii. p. 457. See especially the summary of their opinion at page 571.

† When to a diet of meat which causes a certain absorption of oxygen, fat or sugar is added, the absorption of oxygen lessens (Ranke, Phys. des Menschen, 1868, p. 145); so that it is relative as well as absolute amount which comes into play.

of non-nitrogenous substances, but no experiments have yet shown whether these are fatty or saccharine. It seems to be inferred that it is fat which is thus chiefly acted upon; but this opinion is rather derived from a reference to the universal presence of fat when force is manifested, to the known necessity of it in diet (for though the dog and the rat (Savory) can live on fat-free meat alone, man cannot do so),* and from the large amount of force its oxidation can produce, than from actual observation. If it were true, a broad distinction would be at once drawn between fatty and starchy food, but it is not experimentally proved. If, on the other hand, it were certain that the starchy aliments formed fat in the human body as a rule, this would be a reason for drawing no distinction between the groups. Independent of the argument drawn from bees fed on sugar alone and forming wax, from the fattening of ducks and geese, and the older experiments on pigs, the later experiments of Lawes and Gilbert† seem to clearly show that the fat stored up in fattened pigs cannot be derived from the fat given in the food, but must have been produced partly from nitrogenous substances, but chiefly from the carbo-hydrates. So also it seems now probable that the fat in milk is not derived at once from blood, but from changes of albumen in the lacteal gland-cells. There seems no reason why we should not extend the inference to man. If so, a man could live in perfect health on a diet composed only of fat-free meat and starch, with salts and water, just as he can certainly live (though perhaps not in the highest health) on meat, fat, salts, and water. The carbo-hydrates would then be proved to be able to replace fats. The experiment has not yet been performed to my knowledge, but it seems important it should be.

So also Grouven's experiments seem to suggest that in cattle the carbo-hydrates may split up in the alimentary canal into glycerine, lactic and butyric acids, and carbonic acid and marsh gas. If this be true, in the herbivoræ the starches would be merely another form of fat.

An argument against the fats and carbo-hydrates being mutually replaceable under ordinary conditions in the diet of men is drawn from a consideration of the diets used by all nations. In no case in which it can be obtained is an admixture of starch, in some form, with fat omitted. Moreover, in all cases (except in those nations, like the Esquimaux, who are under particular conditions of food), we find that the amount of fat taken is comparatively small as compared with that of starches. Why should this be, if the two groups serve virtually the same end? Is it a matter of chance that nature has everywhere mixed up fat and carbo-hydrates in those foods on which men thrive best, or is it this mixture which has aided in making men what they are? Analyse almost all the known diets in the world, which are not, so to speak, diets of necessity, and they consist (besides water and salts) of nitrogenous substances, fat, and starches. If the two latter are convertible, why should we not find in some places diets of albuminates and fats only; in others, of albuminates and starches only? Why should there be this singular uniformity of combination? Why, also, should all nations so eagerly seek after starches and sugars, even when fats are available, so that it seems almost an instinct to desire them? The fats when taken into the body enter like the albuminates into the structure of the tissues, of which fat forms in probably all cases an essential part. The carbo-hydrates, on the other hand, in the human body do not appear to be parts of the tissues, though they are contained in the fluids which bathe them, or are contained in them. The

* Ranke could not maintain himself in perfect nutrition on meat alone.—(*Physiol. des Menschen*, 1868, p. 149.)

† On the Sources of the Fat in the Animal Body.—*Phil. Mag.* Dec. 1866.

special direction which the chemical changes in the carbo-hydrates take in the body, seem also to point to special duties. Thus, the formation of lactic and other acids of the same class must arise from carbo-hydrates chiefly or solely. But the formation of these acids is certainly most important in nutrition, for the various reactions of the fluids, which offer so striking a contrast (the alkalinity of the blood, the acidity of most mucous secretions, of the sweat, urine, &c.), must be chiefly owing to the action of lactic acid on the phosphates, or the chlorides, and to the ease with which it is oxidised and removed. If the direction of the changes which the carbo-hydrates undergo within the body is different from that of the fats, the products of these changes must be inferred to play dissimilar parts.

Without pushing these arguments too far, and with the admission that the subject is very obscure, I think we are entitled to assert that the two groups of fats and carbo-hydrates are not so immediately and completely convertible as to permit us to place them together in a classification of diets.

In the second question to which reference was made, viz., that of a nitrogenous substance furnishing fat, or a carbo-hydrate, the case is simpler. The experiments of Voit, and of Lawes, and Gilbert, as well as other considerations, prove that fat may be derived from nitrogenous substances, and there are reasons to believe that a glycogenous substance may also be derived from albuminates.* But this cannot allow us to consider an albuminate as an aliment which may replace fat or starch in the case of man. The digestive system of man is framed so differently from that of the carnivora, that fat must be taken in its own form, for it either cannot be formed in sufficient quantity from albuminates, or the body is poisoned by the excess of nitrogen which is necessarily absorbed to supply it.

With regard to the necessity of all four classes of aliments, it can be affirmed with certainty, that (putting scurvy out of the question) men can live for some time and be healthy with a diet of albuminates, fat, salts, and water. But special conditions of life, such as great exercise, or exposure to very low temperature, appear to be necessary, and under usual conditions of life health is not very perfectly maintained on such diet. It has not yet been shown that men can live in good health on albuminates, carbo-hydrates, salts, and water, &c., without fat.†

The exact effect produced by the deprivation of any one of these classes is not yet known. An excess of the albuminates causes a more rapid oxidation of fat (and in dogs an elimination of water), while an excess of fat lessens the absorption of oxygen, and hinders the metamorphosis of both fat and albuminate tissues. The carbo-hydrates have the same effect when in excess, and appear to lessen the oxidation of the two other classes.

It is now generally admitted that the success of Mr Banting's treatment of obesity is owing to two actions: the increased oxidising effect on fat, consequent on the increase of meat (especially if exercise be combined), and the lessened interference with the oxidation of fat consequent on the deprivation of the starches.

Health cannot be maintained on albuminates, salts, and water alone; but, on the other hand, it cannot be maintained without them.

The salts and water are as essential as the nitrogenous substances. Lime,

* In an addition to physiological evidence from experiments on animals, there are certain forms of diabetes which seem to prove that sugar must be formed either from albuminates or fat, most probably the former.

† In some experiments I have made both with Liebig's essence of meat and Hassall's dried food with bread, I was very much struck with the bad effect produced on the health of the experimentators, and with the immediate relief given by the addition of butter and a larger supply of starch, without augmentation in the amount of nitrogen.

chiefly in the form of phosphate, is absent from no tissue; and there is reason to think no cell growth can go on without it; certainly, in enlarging morbid growths and in rapidly growing cells, it is in large amount.

Whether magnesia is equally important for cell growth and tissue life is less certain. Both lime and magnesia are essential for bone growth and repair; and there can be little doubt that the judicious abstraction or employment of these will form an important part in the treatment of bone diseases.

Potash and soda, in the forms of phosphates and chlorides, are equally important, and would seem to be especially concerned in the molecular currents; forming parts of almost all tissues, they are less fixed, so to speak, than the magnesian and lime salts. It is also now certain, that the two alkalies do not replace each other, and have a different distribution; and it is so far observable, that the potash seems to be the alkali for the formed tissues, such as the blood cells or muscular fibre; while the soda salts are more largely contained in the intercellular fluids which bathe or encircle the tissues.

The chlorine and phosphoric acid have also very peculiar properties; the former apparently being easily set free, and then giving a very strong acid, which has a special action on albuminates, and the latter having remarkable combining proportions with alkalies. Both are furnished in almost all food; the sodium chlorides also separately. Carbonic acid is both introduced and made in the system, and probably serves many uses. Iron is, of course, also essential for certain tissues or parts, especially for the red-blood corpuscles, and for the colouring matter in muscle, and in small quantity is found almost in every tissue, and in every food. The sulphur and phosphorus of the tissues appear to enter especially as such with the albuminates.

Some salts, especially those which form carbonates in the system, such as the lactates, tartrates, citrates, and acetates, give the alkalinity to the system which seems so necessary to the integrity of the molecular currents. The state of malnutrition, which in its highest degree we call scurvy, appears to follow inevitably on their absence; and as they exist chiefly in fresh vegetables, it is a well-known rule of dietetics to supply these with great care, though their nutritive power otherwise is small.

In addition to the substances composing these four classes, there are others which enter into many diets, and which have been termed "accessory foods," or by some writers "force regulators" (like the salts). The various condiments which give taste to food, or excite salivary or alimentary secretions, and tea, coffee, cocoa, alcohol, &c., furnish the chief substances of this class. Much discussion has taken place as to the exact action in nutrition of these substances, but little is definitely know. They may possibly undergo chemical action (oxidation or splitting), or, without doing so, may enter into combination with gland cells or tissues, and modify the currents or molecular movements, and thus be entitled to the term of "force regulators," but it is impossible at present to assign to them their true action.

I have entered so far into this subject merely for the purpose of showing why I believe the old classification of aliments to be correct, and why whatever may be the future direction of physiology, it is not likely to be seriously affected.

Admitting the necessity of a certain amount of each of the four classes for a perfect diet, it has now to be inquired what quantity of each class is necessary, and how the latent energy in each class may be best secured for the purposes of the body.

SUB-SECTION I.—QUANTITY OF EACH CLASS OF PROXIMATE ALIMENT IN A GOOD DIET FOR HEALTHY MEN.

This has been determined partly by observation on a great number of dietaries, and partly by physiological experiments. The general results of the whole are given in the following table :—

Standard diet for a Male European Adult, of average height* (5 *ft.* 6 *in. to* 5 *ft.* 10 *in.*) *and average weight* = 140 *lbs. av.* (66 *kilogrammes*) *to* 160 *lbs.* (72·7 *kilogrammes*), *in moderate work.*

Water-free Substances given Daily.	Ounces Avoir.	Grammes.
Albuminous substances, . . .	4·587	130
Fatty substances, ...	2·964	84
Carbo-hydrates, ...	14·257	404
Salts, ...	1·058	30
Total Water-free food, . .	22·866	648

For a man weighing 153 ℔, and assuming the water-free food to be 23 ounces, each ℔ weight of the body receives in 24 hours 0·15 ounces, or the whole body receives $\frac{1}{105}$ of its weight.

This is the dry food, but a certain amount of water (between 50 and 60 per cent. usually), is contained in it, and adding this to the water-free solids, the total daily amount of so-called dry food (exclusive of liquids) is about 40 ounces. In addition to this, from 50 to 80 ounces of water are taken in some liquid form, making a total supply of water of 70 to 90 ounces, or on an average 0·5 ounces for each ℔ weight of body.

This average amount of food and water varies considerably, from the following causes :—

1. Individual conditions of size, vigour, activity of circulation, and of the eliminating organs, &c. No men eat exactly the same, and no single standard will meet all cases. The usual average range in different male adults is from 34 to 46 ounces of so-called solid food, and from 50 to 80 ounces of water.

2. Differences of exertion. If men are undergoing great exertion they take more food, and, if they can obtain it, the increase is especially in the classes of albuminates and fat.

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* I have copied this table from Moleschott. The numbers are generally received, and are fairly accordant with the observations of numerous other writers. Pettenkofer and Voit give the following (Zeits. für Biol. band ii. p. 523) as the calculation for soldiers—

Dry albuminous substances, ...	148 grammes	= 5·22 ounces.
Fat, ...	103 „	= 3 63 „
Carbo-hydrates, ...	378 „	= 13·3 „

This gives rather more albuminates and fat and less starch than Moleschott's table. In their experiments with two healthy men in their experimental-room, the amount was, albuminates, 137 grammes ; fat, 117 grammes ; and carbo-hydrates 352 grammes daily. Ranke, however, gives rather lower numbers—viz., 100 grammes of albuminates, 100 of fat, and 240 of starch (Phys. des Mem. 1868, p. 158), for moderate work.

Average Daily Water-free Diet of an adult Man in very laborious Work, or of a Soldier on Service and in the Field.*

	Ounces avoir.
Albuminates,	6 to 7
Fats,	3·5 to 4·5
Carbo-hydrates,	16 to 18
Salts,	1·2 to 1·5
Total water-free food,	26·7 to 31·0

The amount of water is increased, but is very various according to circumstances, and is not so much augmented apparently as the solid food. On the other hand, men in rest will usually eat less; at any rate, the weight and health of the body can be maintained on less.

Average Daily Diet of Men in Quietude.

	Rest.	Subsistence diet (Playfair)† *i.e.*, sufficient for the internal mechanical work of the body.
Albuminates,	2·5	2
Fats,	1	·5
Carbo-hydrates,	12	12
Salts,	·5	·5
Total water-free food,	16·0	14·0

The subsistence diet, though it will keep a man alive, will probably not prevent him from losing weight, and therefore is not really sufficient.

3. Differences of climate. It is a matter of general belief that more food is taken in cold seasons and in cold countries than in hot. It is supposed that more energy in some form (finally in that of heat) is necessary, and more food is required; but there may be other causes, such as varying exertion.

In the case of any diet the articles of which are known, the amounts of the four classes of alimentary principles may be calculated from a table of mean composition. The following is compiled from, in most cases, several analyses by different authors, those analyses being selected which seem best to represent the food of the soldier.‡

Whenever practicable, the nutritive value should be calculated on the raw substance, as the analyses of cooked food are more variable. It must then be seen that no loss occurs in cooking.

The mode of using the table is very simple; the quantity of uncooked meat or bread being known, and it being assumed or proved that there is no loss in cooking, a rule-of-three brings out at once the proportion. Thus, the ration allowance of meat for soldiers being 12 oz., 2·4 oz. or 20 per cent. is deducted

* Playfair gives the diet of a prize-fighter in training as 9·8 oz. albuminates, 3·1 fats, and 3·27 starch and sugar. There are 690 grains of nitrogen, and 4366 grains of carbon.

† The amount of two ounces of albuminates is that fixed by Playfair (food of man in relation to his useful work) as furnishing by calculation the amount of force sufficient to carry on the internal work of the body. Although our views are now somewhat modified on this point, I believe the numbers express pretty accurately the actual food which will keep a man alive.

‡ Of course such tables are merely approximative; but they are very useful as giving a general idea of a diet, although they are not accurate enough to be used in physiological inquiries. In Dr Letheby's Cantor lectures on food (Chemical News, August 1868); in Dr Horace Dobell's work on Diet and Regimen, and in Dr Beddoe's treatise on Hospital Diet, fuller tables will be found. No two tables will, however, be found quite alike.

for bone, as the soldier does not get the best parts. The quantity of water in the remaining 9·6 ounces will be $\frac{75 \times 9{\cdot}6}{100} = 7{\cdot}2$, and the water-free solids will be 2·4 ounces. The albuminates will be 1·44 ounce; the fats, ·8064; and the salts, ·1536 ounce.

Table for Calculating Diets.

Articles of the Soldier's Diet.	In 100 Parts.				
	Water.	Albuminates.	Fats.	Carbohydrates.	Salts.
Uncooked meat of the kind supplied to soldiers,—beef and mutton. Bone constitutes $\frac{1}{5}$th of the soldier's allowance,*	75	15	8·4	...	1·6
Uncooked meat of fattened cattle. Calculated from Lawes' and Gilbert's experiments. These numbers are to be used if the meat is very fat, . .	63	14	19	...	3·7
Cooked meat,† roast, no dripping being lost. Boiled assumed to be the same, . .	54	27·6	15·45	...	2·95
Bread, white wheaten of average quality, ...	40	8	1·5	49·2	1·3
Flour, wheat average quality, .	15	11	2	70·3	1·7
Biscuit, ...	8	15·6	1·3	73·4	1·7
Rice, ...	10	5	·8	83·2	0·5
Oatmeal‡ (von Bibra), . . .	12	16	6·8	63·2	2 §
Oatmeal (Letheby), ...	15	12·6	5·6	63·0	3
Maize (Poggiale), ...	13·5	10	6·7	64·5‖	1·4
Peas (dry), ...	15	22	2	53‖	2·4
Potatoes, ...	74	1·5	·1	23·4	1
Carrots (cellulose excluded), .	85	·6	·25	8·4	·7
Cabbage, ...	91	·2	·5	5·8	·7
Butter, ...	6	·3	91	...	variable, taken as 2·7
Egg (10 per cent. must be deducted for shell from the weight of the egg),. . . .	73·5	13·5	11·6	...	1
Cheese, ...	36·8	33·5	24·3	...	5·4
Milk (sp. gr. 1030 and over), .	86·7	4	3·7	5	·6
„ (sp. gr. 1026), ...	90	3	2·5	3·9	·5
Sugar, ...	3	...	...	96·5	·5

* The gelatine of the meat is reckoned with the albuminates; it is not certain what deduction should be made on account of its lower nutritive value, which is about ¼th that of albumen (Bischoff).

† These numbers are taken from John Ranke's analysis.

‡ I have taken these numbers from the second analysis given by Von Bibra (Die Getreidearten und das Brod, 1860, p. 324), but the amount of albuminates and fats is both larger than in other analyses, and possibly also more cellulose is left in many specimens than the sample analysed by Von Bibra. I have, therefore, given another analysis by Letheby.

§ Silica of the husk deducted.

‖ There is also some indigestible cellulose in maize, peas, and carrots, which is not included in the table.

In the case of salt beef or pork, it is not certain how the value should be calculated. The analyses by Girardin give for uncooked salt beef—

49·11	per cent.	of water,
24·82	,,	fibrin and cellular tissue,
3·28	,,	extractive matters,
·7	,,	albumen,
·18	,,	fat,
21·07	,,	soluble salts;

but the analysis of the brine shows that much of the nutritious matters, organic and mineral (phosphoric acid, lactic acid, magnesia), have passed out of the meat.* Liebig has reckoned the nutritive loss at one-third, or even one-half. It appears from Kühne's observations, that myosin is soluble in a 10 per cent. solution of chloride of sodium, and hence a large quantity of this substance necessarily passes into the brine. Analyses show, it is true, a large percentage of fibrin and cellular tissue in salt meat, but this is made up of indigestible nitrogenous substances, which afford, probably, little real nutritive material. Perhaps salt beef may be reckoned as equal to two-thirds the quantity of fresh beef; this estimate is certainly quite high enough.

The precise amount of the mineral matters of the various articles can be calculated, whenever necessary, from the following list, compiled in great part from Moleschott's elaborate tables. The mode of calculation is the same as above. For example, it is required to know the amount of chloride of potassium in the soldier's ration of meat, which is taken, we will say, as 9·6 ounces without bone—

$$\frac{\cdot 154 \times 9\cdot 6}{100} = \cdot 014784 \text{ oz., or } 6\cdot 468 \text{ grains.}$$

The proportion of the nitrogenous substances to the fats and carbo-hydrates are in the standard diet as follows:—

Albuminates, . . .	1
Fat, ...	·6 nearly.
Carbo-hydrates, . . .	3

This is as 1 of nitrogenous to 3·6 of non-nitrogenous; but, as is often done, if 1 part of fat be reckoned as equal to 2·4 parts of starch, the proportion will be 1 of dry nitrogenous to $(\cdot 6 \times 2\cdot 4) + 3)$, $4\frac{1}{2}$ nearly of dry non-nitrogenous or carboniferous substances, taken as starch.

Amount of Nitrogen and Carbon.—As the phenomena of nutrition are chiefly owing to the various chemical interchanges of nitrogen and carbon, and in some cases of hydrogen, with oxygen, it may be desired to calculate the amount of nitrogen and carbon in any diet. This may be done in two ways.

1. Calculate out the dry albuminates, fat, and carbo-hydrates in ounces, and then use the following table:—

Nitrogen and Carbon in grains.	Nitrogen.	Carbon.
1 ounce of water-free albuminate,	69	233
1 ounce of water-free fat, . .	...	345·6
1 ounce of water-free carbo-hydrate (except lactin),		194·2†

* Liebig found that the brine is saturated with the juice of meat, and Mr Whitelaw (*Chemical News*, March 1864) has shown that extract of meat may be obtained by dialysis from the brine.

† These numbers are thus obtained: the various dry albuminates contain from 15·4 to 16·4 per cent. of nitrogen. I have selected 15·8 for the range for European diet, as it represents the nitrogen of syntonin; there is 53·5 per cent. of carbon, fat contains 79 per cent., starch and sugar 44·4, and lactin 40 per cent. of carbon. I have not taken into account any hydrogen in excess of that forming water with the oxygen of the food.

Percentage of Mineral Substances in the different Undried Articles of Food.

	Fresh Beef.	Salt Beef.	Fresh Pork.	Ham or Salt Pork.	Bread.	Wheat.†	Rice.	Maize.	Beans and Peas (dry).	Potatoes.	Oats, whole grain.	Cabbage.	Cheese.	Eggs.	Milk.
Total ash, per cent. of undried substances,	1·6*	1·5	1·11	6·6	1·3	1·996	·2	1·28	2·4	1·	2·59	1·52	5·4	1·05	·548
Chloride sodium	·310	·691	·012	5·7	...	·041	...	...	...	·013	...	·156	3·45	·15	·041
„ potassium	·154	...	...	·173	...	...	...	...	...	·058	...	...	...	·15	·127
Potash,	·54	·398	·42	·35	...	·446	·1	·396	·98	·626	·34	·424	·199	·12	·056
Soda,	·026	...	·045	...	...	·191	·013	...	·24	...	·024	·257	·3	·008	·013
Lime,	·051	·012	·083	·027	...	·057	·035	·016	·236	·026	·089	·223	·523	·091	·128
Magnesia,	·023	·03	·004	·035	...	·221	·021	·200	·185	·053	·196	·064	·02	·022	·014
Oxide iron or phosphate,	·011	·017	·494	·006	...	·019	·012	...	...	·005	·026	·016	·007	·012	·003
Phosphoric acid,	·435	·346	·054	·312	...	·998	·312	·645	·646	·179	·493	·217	·9	·35	·162
Sulphuric acid,	·036	·01	...	·013	...	·002	...	...	·07	·047	·016	·089	...	·017	·001
Chlorine,	...	...	...	...	...	...	...	...	·025	...	...	...	...	...	...
Silica,	·014	·004	...	...	...	·021	·007	·001	...	·018	1·41	·064	...	·005	...

* The ash of meat is often put higher,—viz., about 4 per cent. Lawes' and Gilbert's analysis give the mean as 3·69 per cent.

† Some of the salts of wheat are lost with the bran, and the percentage of good white flour is not more than ·8, or 1 per cent., while the salts in the bran are 4·4 per cent. The ingredients have the same relation as in the Table, the phosphates of magnesia and potash being in greatest amount. If the numbers in the Table are halved, the amount in flour is given closely enough.

If the diet be largely of milk, the amount of lactin (milk carbo-hydrate) must be determined; 1 ounce of lactin contains 175 grains of carbon.

2. In the following table, the calculation of these ingredients per ounce has been made; the substance being supposed to be in its natural state, and to have the composition already assigned to it in the former table.

Substance.	One ounce (=437·5 grains) contains in its natural state in grains.			
	Water.	Nitrogen.	Carbon.	Salts.
Uncooked meat (beef), . .	328	10·35	64	7
Uncooked fat meat (beef), . .	275·6	9·6	98·3	16
Cooked meat, ...	236	19	117·7	13
Bread, ...	175	5·5	119	5·6
Wheat flour, ...	65·6	7·6	169	7·4
Biscuit, ...	35	22·7	183	7·4
Rice, ...	43·7	3·5	176	2·2
Oatmeal (Letheby's numbers),	65·6	8·7	172	13
Maize, ...	59	7	176	6
Peas, ...	65·6	15	161	10
Potatoes, ...	324	1	49	4·4
Carrots, ...	398	·4	18	3
Butter, ...	26	·2	315	11·8
Egg, ...	321	9·3	71·5	4·4
Cheese, ...	161	23	162	23·6
Milk, ...	380	2·75	30·8	2·6
Sugar, ...	13	...	187	2

Some addition must be made to this table. I found the steak used for the patients at Netley to contain as much as 14·22 grains of nitrogen per ounce, and this number should be used for the best hospital steaks and chops. Hospital bread contains only 3·6 grains of nitrogen in each ounce of crumb, and 4·78 in each ounce of crust.

The standard daily diet for an adult man, calculated in this way, gives—

Nitrogen, ...	316·5 grains,
Carbon, ...	4862 „
Salts, ...	461 „

The usual range is from 250 to 350 grains of nitrogen for adult men, and the extreme range is from 2 to 7 ounces of dry albuminate, or from 138 grains of nitrogen (which is the smallest amount necessary for the inner movements of the body, and the bare maintenance of life, as calculated by Playfair), to 483 or 500 grains, which is the amount taken under very great exertion. Edward Smith's careful observations on ill fed and fairly fed operatives, give a range of from 135 grains of nitrogen, and 3271 grains of carbon (in London needlewomen) to 349 grains of nitrogen and 6195 grains of carbon (in Irish farm labourers. Usually, however, in what are almost starvation diets, the nitrogen is 180 to 200 grains (Edward Smith's investigations into the food in Lancashire during the cotton famine). The carbon ranges from 3600 to 5800 or 6000 grains. The amount of the salts (461) appears rather large; it is difficult to test it by determining the salts in the excreta, as so much sodium chloride and lime salts are lost through the skin, and some of the excreted salts may also be mere surplusage. The salts seem to be made up of chlorine, 120 grains; phosphoric acid, 50 grains; potash, 40; soda, 40; lime, about 4 grains

by the urine,* and some by the bowels; magnesia, 4·7 grains by the urine, and a considerable amount by the bowels; and iron, the amount of which is quite uncertain.

Actual experiment has, to a great extent, confirmed the conclusions drawn from a study of these dietaries. Pettenkofer and Voit, in two healthy men, determined many times the amount of nitrogen during common exercise, and found it to be 19·82 grammes, or 305·8 grains. I experimented on two healthy average men in common work, and found the amount which kept them in perfect health and uniform weight, was 293 and 294 grains of nitrogen in twenty-four hours. All these determinations are near Moleschott's numbers. The amount of carbon is, however, perhaps too large. In Ranke's careful experiments in a state of rest, there were consumed by a man 160·6 lbs. weight, 240 grains of nitrogen, and 3531 grains of carbon; as a rule, the later experiments show that the amount of carbon was put too high.

SUB-SECTION II.—ON THE FORCE OBTAINABLE FROM THE VARIOUS ARTICLES OF FOOD.

The possible amount of energy which can be manifested in the body will be the result of two conditions: first, the amount of potential energy stored up in the food, and which is, of course, easily determined and expressed in terms of units of heat or of motion; and second, the extent to which the processes in the body can liberate and apply this energy. For example, an ounce of albumen can give rise to a certain heating effect if it be burnt in oxygen; but in the body thorough oxidation can never occur, for some of the constituents of the albumen pass out incompletely oxidised in the form of urea. An ounce of sugar, on the other hand, is as a general rule destroyed to the fullest extent, and ends in carbonic acid and water, and its actual energy in the body, under whatever form it appears, is equal to its theoretical energy.

Tables have been given by chemists showing the amount of force which may be manifested. The results have been obtained in some cases by calculation, and in others by direct experiment. In the following table I have selected Dr Frankland's experimental results as the most exact, but they agree very closely with the theoretical results, particularly with those given by Playfair† and others. Thus, Playfair calculated that one ounce of dry albumen would give rise by oxidation to heat sufficient to raise 126·5 kilogrammes of water 1° cent., or to lift 173 tons 1 foot high,‡ while Frankland's experimental number is almost identical—viz., 168·68 tons, lifted a foot.

A table of this kind is useful in showing what can be obtained from our food, but it must not be supposed that the value of food is in exact relation to the possible energy which it can furnish. In order that the force shall be obtained, the food must not only be digested and taken into the body properly prepared, but its energy must be developed at the place and in the manner proper for nutrition. The mere expression of potential energy cannot fix dietetic value, which may be dependent on conditions in the body unknown to us. For example, it is quite certain, from observation, that gelatine cannot fully take the place of albumen, though its potential energy is little

* I have followed Byasson in this and in the amount of magnesia in the urine, as his experiments appear carefully done.—*L'Activité Cérébrale et la Composition des Urines*, par le Dr H. Byasson, Paris, 1868, p. 43.

† On the Food of Man in relation to this useful Work. 1865.

‡ For an explanation of this term, see the chapter on EXERCISE.

inferior,* and it is easily oxidised in the body. But owing to some circumstances, yet unknown, gelatine is chiefly destroyed in the blood and gland cells, and its energy, therefore, has a different direction from that of albumen. So also of the potential energy, it is quite possible that all is not usefully employed. The tables of energy give broad indications, and can be used in a general statement of the value of a diet; but at present they do not throw light on the intricacies of nutrition.†

Energy developed by One Gramme or One Ounce of the following Substances when oxidised in the Body:—

Name of Substance.	Per cent. of Water.	One gramme will equal kilogrammemetres of energy.	One ounce will equal foot-tons of energy, or, in other words, would raise the undergiven number of tons 1 foot high.§
Beef (lean),	70·5	604	55
Veal (lean),	70·9	496	45·3
Ham (lean, boiled),	54·4	711	64·9
Bread crumb,‡	44	910	83
Flour,	...	1627	148·5
Ground rice,	...	1591	145·3
Oatmeal,	...	1665	152
Pea meal,	...	1598	146
Potatoes,	37	422	38·5
Carrots,	86	220	20
Cabbage,	88·5	178	16·2
Butter,	...	3077	280·9
Egg (white of),	86·3	244	22·3
Egg (yolk),	47	1400	127
Cheshire cheese,	24	1846	168·5
Arrowroot,	...	1657	151·3
Milk,	87	266	24·3
Sugar (lump),	...	1418	129·5
Ale (Bass' bottled),	88·4	328	30
Porter (Guinness' Stout),	88·4	455	41·5

Sub-Section III.—On the Relative Value of Food of the same Class.

The chemical composition of animal and vegetable albuminates is very

* One gramme of dry isinglass will develop 4520 heat-units when burnt in oxygen; one gramme of dry boiled ham, 4343; one gramme of dry beef, 5313 heat-units. (Frankland, *op. cit.* p. 196.) The potential energy of isinglass is more than that of ham, but its nutritive power is far inferior.

† The following numbers have been calculated by Lethcby from Frankland's figures. (Cantor Lectures on Food, *Chemical News*, Oct. 1868.)

	Energy when oxidised in the body. Lbs. lifted a foot	=	Tons lifted a foot.
Subsistence diet (= 2 ounces of dry nitrogenous food, and 13·2 ounces of dry carbonaceous, taken as starch)	6307078	=	2815·6
Working diet (= 6 ounces of dry nitrogenous and 22 ounces of carbonaceous	13311290	=	5942

‡ The crust of bread is very nearly double the amount.

§ The first and second columns are taken from Dr Frankland's paper in the Philos. Trans., Sept. 1866, p. 196. The third column is calculated from the second, by multiplying by 28·35 (the number of grammes in an ounce avoirdupois), and then by ·003221, to bring metre-kilogrammes into foot-tons. The substances are not dried, but in their natural state.

similar, and they manifestly serve equal purposes in the body. The meat-eater, and the man who lives on corn, or peas and rice, are all equally well nourished. But it has been supposed that either the kind or the rapidity of nutrition is different, and that the man who feeds on meat, or the earnivorous animal, will be more active, and more able to exert a sudden violent effort, than the vegetarian, or the herbivorous animal, whose food has an equal potential energy, but which is supposed to be less easily evolved. The evidenee in favour of this view seems to me very imperfeet. The rapid movements of the carnivora have been contrasted with the slow, dull action of domestic cattle; but, not to speak of the horse, whoever has seen the lightning movements of the wild antelope or cow, or even of the wild pig, who is herbivorous in many cases, can doubt that vegetable feeders can exert a movement even more rapid and more enduring than the tiger or the wolf? And the evidence in men is the same: in India, the ill-fed people, on rice and a little millet or pea, may indeed show less power; but take the well-fed corn-eater, or even the well-fed rice and pea eater, and he will show, when in training, no inferiority to the meat-eaters. An argument has been drawn from the complicated alimentary canal of the herbivoræ, but probably this is chiefly intended to digest the cellulose, and in these the digestion and absorption of albuminates may be as rapid as in other animals.

It appears from Dr Beaumont's experiments that animal food is digested sooner than farinaceous, and possibly meat might therefore replace more quickly the wasted nitrogenous tissue than bread or peas; and it may be true, as asserted, that the change of tissue is more quick in meat-eaters, who require, therefore, more frequent supplies of food. Even this, however, seems to me not yet thoroughly proved.

It has been also supposed that there is a difference in the nutrition of even such nearly allied substances as wheat and barley, but the evidence is imperfect, and is perhaps dependent on differences in ease of digestion.

With respect to the fats, their differences of nutrition are probably dependent entirely on facility of digestion and absorption. The animal fats appear easier of absorption than the vegetable. Berthé* found that in addition to the fat in his ordinary diet, he could absorb 30 grammes, or 1·059 ounces of cod-liver oil, butter, or other animal oil; in some instances $1\frac{3}{4}$ ounces were absorbed. Of vegetable oils only 20 grammes, or 0·7 ounces, were absorbed. When, in experiments with cod-liver oil, 40 grammes were taken, 31·5 were absorbed, 8·5 passed by the bowels; when 60 grammes were taken, 48 were absorbed and 12 passed. But when he took 60 grammes daily, the amount of fat in the fæces gradually increased, until 50 grammes daily passed off in that way. In the dog, however, Bischoff and Voit found that 250 and 300 grammes (8·8 and 10·5 ounces) of butter were easily absorbed. During the digestion of the fats they are, probably, in part decomposed; and the fatty acids, like the acids derived from the starch, must, to a certain extent, antagonise the introduction of alkali in the food.

The various carbo-hydrates are generally supposed to be of equal value. Starch requires a little more preparation by the digestive fluids than grape sugar, into which it appears first to pass; but the change is so rapid that it can hardly be made a point of difference between them. It is observable, however, that even when sugar is very cheap and accessible it is not used to entirely replace stareh; but this, perhaps, may be a matter of taste.

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* Ludwig's Phys. band ii. p. 668.

Sub-Section IV.—The Digestibility of Food.

In order that food shall be digested and absorbed, two conditions are necessary; the food must be in a fit state to be digested, and it must meet in the alimentary canal with the chemical and physical conditions which can digest and absorb it.

Fitness for digestibility depends partly on the original nature of the substance, as to hardness and cohesion, or chemical nature, and partly on the manner in which it can be altered by cooking. Tables of degree of digestibility have been formed by several writers, and especially by Dr Beaumont, by direct experiment on Alexis St Martin; but it must be remembered that these are merely approximative, as it is so difficult to keep the conditions of cooking equal.*

Rice, tripe, whipped eggs, sago, tapioca, barley, boiled milk, raw eggs, lamb, parsnips, washed and baked potatoes, and fricasseed chicken, are the most easily digested substances in the order here given; the rice disappearing from the stomach in one hour, and the fricasseed chicken in $2\frac{3}{4}$ hours. Beef, pork, mutton, oysters, butter, bread, veal, boiled and roasted fowls, are rather less digestible; roast beef disappearing from the stomach in three hours, and roast fowl in four hours. Salt beef and pork disappeared in $4\frac{1}{4}$ hours.†

As a rule, Beaumont found animal food digested sooner than farinaceous, and in proportion to its minuteness of division, and tenderness of fibre.

The admixture of the different classes of food aids digestibility; thus fat taken with meat aid the digestion of the meat; some of the accessory foods probably increase the outpour of saliva, gastric or enteric juice, &c.

The degree of fineness and division of food; the amount of solidity and of trituration which should be left to the teeth, in order that the fluids of the mouth and salivary glands may flow out in due proportion; the bulk of the food which should be taken at once, are points seemingly slight, but of real importance. There is another matter which appears to affect digestibility, viz., variety of food.

According to the best writers on diet, it is not enough to give the proximate dietetic substances in proper amount. Variety must be introduced into the food, and different substances of the same class must be alternately employed. It may appear singular that this should be necessary; and certainly many men, and most animals, have perfect health on a very uniform diet. Yet, there appears no doubt of the good effect of variety, and its action is probably on primary digestion. Sameness cloys; and with variety, more food is taken, and a larger amount of nutriment is introduced. It is impossible, with rations, to introduce any great variety of food; but the same object appears to be secured by having a variety of cooking. Formerly, the soldier had nothing but boiled beef; now, he has roast meat twice in the week, and stews occasionally; and a portion of his flour is made into puddings. In the case of children especially, a great improvement in health takes place when variety of cooking is introduced; and by this plan (among others), Dr Balfour succeeded in marvellously improving the health of the boys in the Duke of York's School.

The internal conditions of abundance and proper composition of the alimentary fluids, and the action of the muscular fibres in moving the food, so that it shall be submitted to them, depend on the perfection of the nervous currents, the vigour of circulation, and the composition of the blood.

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* The preparation of food by cooking is so important a matter, that the art of cookery ought not to be considered as merely the domain of the gourmand. Health is greatly influenced by it, and it is really a subject to be practically studied by chemists and physiologists.

† An extended table is given in Cox's excellent edition of Combe's Physiology of Digestion, p. 123.

Many of the digestive diseases the physician has to treat depend on alterations in those conditions by which the food is left undigested, or only imperfectly digested.

SECTION II.

THE FOOD OF THE SOLDIER—ARMY REGULATIONS.

The Army Medical Regulations place the food both of the healthy and sick soldier under the control of the medical officer. He is directed to ascertain that the rations of the healthy men are good, and that the cooking is properly performed; the amount of food for the sick is expressly fixed. On taking the field, the principal medical officer is ordered to advise on the subject of rations, as well as on all other points affecting the health of the troops. It will thus be seen that a great responsibility has been thrown on the Medical Department, and that its members will be called upon to give opinions on the quantity of all kinds of food supplied to soldiers; the composition of diet; on the quality and adulteration of the different articles; and on their cooking and preparation.

In the case of soldiers and sailors, definite quantities or rations of food must be given. It is, of course, impossible to fix a ration which shall suit all persons. Some will eat more, some less, but certainly every scale of rations should err on the side of excess rather than defect.

The following are the rations of the chief European armies :—

English Soldier on Home Service.

The English soldier receives from Government 1 lb. of bread, and $\frac{3}{4}$ lb. of meat (for which he pays $4\frac{1}{2}$d.), and buys additional bread, vegetables, milk, and groceries. The following table shows his usual food.

Nutritive Value in Ounces (avoir.) and Tenths of Ounces.

Articles.	Quantity taken daily in oz. and tenths of oz.	Water.	Nitrogenous Substances.	Fat.	Carbohydrates.	Salts.
Meat, . . .	12 oz. (of which $\frac{1}{8}$th is bone.)	7·2	1·44	0·8	...	·154
Bread, . . .	24 oz.	9·6	1·92	0·36	11·73	·312
Potatoes, . .	16 „	11·84	0·24	0·02	3·75	·020
Other vegetables,	8 „	7·28	0·16	0·04	0·46	·050
Milk, . . .	3·25 „	2·92	0·1	0·08	0·13	·016
Sugar, . . .	1·33 „	0·04	...	...	1·28	·006
Salt, . . .	0·25 „	...	...	...	...	·25
Coffee, . . .	0·33 „	...	...	...	...	...
Tea, ...	0·16 „	...	...	...	...	...
Total quantity,	65·32 oz.	38·88	3·86	1·30	17·35	·808

Calculating this by the former tables, it would give—

		Grains.
Nitrogen, ...		266
Carbon in albuminates, ...	899·38	
Carbon in fats, ...	449·28	4718
Carbon in starches, ...	3369·37	

The quantity of nitrogen is considerably below that of the standard diet, while the amount of carbon is nearly correct, only this is given chiefly in the form of carbo-hydrates, and not as fat. The diet would be improved by the addition of more meat or of cheese, and by the addition of butter or of oil. So also, while fresh succulent vegetables are sufficient, the use of peas and beans, as in the French army, would be very desirable.*

It is right, however, to say that Dr Playfair† has calculated the food of the English soldier rather higher, viz. :—

Albuminates, . .	4·250	ounces.
Fat, ...	1·665	,,
Starch, &c., . .	18·541	,,
Mineral matter, . .	·789	,,
Total, . .	25·245	,,

This would give 293 grains of nitrogen and 5566 of carbon. Using Dr Frankland's table, and taking the bread $\frac{1}{6}$th crust and $\frac{5}{6}$ths crumb, and the "other vegetables" as cabbage, the total force obtainable in the body from the soldier's daily diet appears to be equal to lifting 3848·5 tons one foot. The amount for the internal and external mechanical work of the body being taken at 700 tons lifted a foot, there remains 3148 tons for the equivalent amount of heat and all the other processes. (See chapter on EXERCISE for further discussion.)

The food (issued and bought) of nine companies of the Royal Engineers (who receive extra working pay), serving at home in 1865, has been carefully calculated by Dr Playfair: the mean was—

Albuminates, . .	5·08	ounces.
Fat, ...	2·91	,,
Starch, &c., . .	22·22	,,
Mineral matter, . .	·93	,,

This would give the nitrogen as equal to 350 grains, and is certainly a good diet for hard-working men.

The accessory foods are rather deficient in the soldier's food, and vinegar especially should be used. Robert Jackson very justly insisted on the importance of vinegar as a digestive agent and flavourer, as well, no doubt, as an anti-scorbutic. He remarks on the great use of vinegar made by the Romans, and possibly the comparative exception which they had from scurvy was due to this. In the time of war this ration is quite insufficient. (See WAR.)

The diet of the soldier on foreign stations is stated under the several headings when it differs materially from that of home service, and the alterations in the diet which should be made under circumstances of great exertions are given in the proper chapter.

In the time of Edward VI. the English soldier's rations during war were—meat 2 ℔, bread 1 ℔, wine 1 pint (Froude).

In the military prisons the diet is as follows :—‡

* That the food of the English soldier is deficient, especially for the younger men, is known also from evidence. The late Director-General (Sir James B. Gibson) strongly urged on the authorities the desirability of increasing the ration of meat, and in the late report on the recruiting of the army the same point was brought forward. I have made inquiries from soldiers, and find the recruits and young soldiers could eat much more; though the old soldiers, many of whom have been long accustomed to take spirits, and who have injured their digestive powers by so doing, take less food. I have no doubt, however, that, taking the army through, the ration, especially of meat, is not enough.

† On the Food of Man in relation to his Useful Work, 1865, p. 11.

‡ Report on Military Prisons for 1863. Blue-book, 1864, p. 22.

1. Not at hard labour—

Daily Ration in Ounces.

	Under 56 days.	After 56 days.
Oatmeal, . . .	8	10
Indian meal, . .	9	12
Bread, ...	8	8
Milk, ...	24	24

2. At hard labour—

First Class.—For four days the same as for prisoners not at hard labour; on Sunday, Tuesday, and Thursday, the following:—Oatmeal, 8 oz.; beef (raw, without bone), 8 oz.; potatoes, 32 oz. (or bread, 8 oz.; soup, thickened with 1 oz. of oatmeal, 1 pint; and 2 oz. of vegetables, with pepper and salt); bread, 8 oz.; milk, 16 oz.

Second and Third Class.—Same as prisoners without hard labour, except on Tuesday and Thursday, when the diet is the same as for the first class.

3. In solitary confinement—

16 oz. of bread and water for three days (or for seven at the option of the visitor), then the same diet as for prisoners without hard labour.

Rations of the French Soldier.[*]

In time of Peace.

In time of peace the different arms of the service are somewhat differently fed, according to the contribution which the men make themselves, as in England. Thus the infantry of the line pay 45 centimes daily, the cavalry of the line 43 centimes, and the imperial guard 50 centimes. In time of peace the State furnishes only bread and fuel, the soldier buys the rest.

Infantry of the Line.

	Grammes.	Ounces avoir.
Munition bread, . . .	750	26·5
White bread for soup, . .	250	8·8
Meat (*uncooked*), . . .	250	8·8
Vegetables, ...	160	5·6
Salt, ...	15	0·5
Pepper, ...	2	0·07 = 31 grains.
Brandy, ...	50 C.C.	0·1¾ ounce.
Total, exclusive of brandy, . . .		50·27

If biscuit is issued, 550 grammes (or 19·4 ounces) are given in place of bread. If salt beef is used, 250 grammes (8·8 ounces) are issued, and 200 (7 oz.) of salt pork. Haricot beans frequently form part of the vegetables.

Analysed by the table for calculating diets, and deducting 20 per cent. from the meat for bone, the water-free food of the French infantry soldier is, in ounces and tenths—

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[*] Code des Officiers de Santé, par Didiot, 1862, pp. 481, *et seq.*

	Water.	Albuminates.	Fats.	Starches.
Bread, ...	14	2·8	0·5	17·8
Meat, ...	6·6	1·4	0·8	...
Vegetables (taken as cabbage),	5·09	·11	·028	·32
Total, ...	59·69	4·31	1·328	18·12

In Algiers the ration of bread is also 740 grammes, or 26·5 ounces, and 8·8 ounces for soup, or biscuit 643 grammes. The meat is the same; 60 grammes of rice and 15 of salt are issued, and on the march, sugar, coffee, and ¼ litre of wine.

In time of War.

	Total.	Water.	Albuminates.	Fats.	Starches.
Meat (without bone), .	7	5·2	1·1	0·7	...
Bread, ...	26·5	10·6	2·1	0·4	13·5
Or Biscuit, ...	(18·5)	...	...	...	...
Rice, ...	2	0·2	0·78	0·018	1·7
Dried vegetables, . .	2	...	0·5	...	1·5
Salt beef or salt pork, .	8·75	6·58	1·4	09·8	...
Total, ...	46·25	22·58	5·18	1·898	16·9
Salt, ...	½ oz.	Total water-free food, 23·7 oz.			
Wine, ...	½ pint				
Beer, ...	1 pint				
Brandy, ...	¼ oz.				
Vinegar, ...	...				
Sugar, ...	1 oz.				

In the Crimea the ration was rather larger than this; 10½ ounces of fresh meat and 8 of salt pork being issued, and haricot beans, with or without rice.

Prussian Soldier.*

The soldier receives his pay every ten days—*i.e.*, three times a-month; it amounts to 3 thalers (or 9 shillings English) per month,† or 3 silbergroschen (= 3½ pence nearly) a-day. Out of this he has to defray the cost of a warm dinner ("menage") at the rate of 1¼ silbergroschen (= 1½ penny); and he also pays a mess contribution, varying according to the market prices of food.

Bread.—In garrison, the daily ration of bread is 1 ℔ 12 loth‡ = 24·67 English ounces, and is issued in loaves for four days, weighing 98·68 English ounces. On the march, in some fortresses, and to prisoners sentenced to hard labour, the larger bread ration of 1 ℔ 26 loth = 32·93 English ounces, daily is issued. On the march, the soldier, when quartered in private houses, gets

* For this information I have to thank my friend Dr Roth, of the Prussian army.

† Lance-corporals and privates which have engaged themselves to serve a longer term of years receive an additional pay—1 thaler (3 shillings) per month.

‡ The Prussian weights are now assimilated to the French; the Prussian pound is = ½ kilogramme or 500 grammes; the loth = 16·66 grammes or ·5879 oz. avoir.

his mess contribution deducted, but has the right to be supplied by his landlord with 32·93 (English) oz. rye bread, 8·82 (English) oz. meat, vegetables, and salt, the latter in sufficient quantity for two meals (dinner and supper). Soldiers in cantonments or bivouacs are provided with food from the stores, and their mess contribution is, of course, deducted.

The rations in time of peace are divided into the smaller and the larger victualling rations.

	Smaller Ration, in ounces avoir.	Larger Ration for Marches, &c., as supplied from the Military Stores, in ounces avoir.
Bread, ...	24·67	32·93
Meat (raw), ...	5·28	8·82
Rice, ...	3·22	4·10
Or unhusked Barley (Groats), .	4·10	5·28
Or Peas or Beans, . . .	8·22	10·37
Or Potatoes,*	$\frac{3}{8}$ gallon.	·5 gallon.
Salt, ...	0·87	0·87
Coffee, ...	0·468	0·468

Troops, when travelling on railway or on steamers, receive an additional pay of $2\frac{1}{2}$ silbergroschen (= 3 pence) per man for refreshments. Should the travelling last longer than 16 hours, the additional pay is doubled.

In the war in Schleswig, in 1864, the meat was doubled on field days. Biscuit was only used when bread could not be obtained.

AUSTRIAN SOLDIER.

In time of Peace (in ounces avoir.)

	Total.	Water.	Nitrogenous substances.	Fatty substances.	Starchy substances.
Bread, . .	31·75	12·7	2·54	0·476	16·190
Meat (without bone),	7·5	5·625	1·2	0·675	...
Flour, . .	1·25	0·175	0·175	0·025	0·875
	40·50	18·500	3·915	1·176	17·065

Total solids (water-free food) = 22·156.

The amount is pretty good, but there is too great a preponderance of bread, and there is too great sameness. The fat is in too small a quantity; the nitrogenous substances are too small.

In time of War.

It is difficult to calculate the daily ration, as there is a weekly issue of many substances. On four days, fresh pork is issued; the total amount being 26 oz., or $6\frac{1}{2}$ oz. daily. On one day, 6 oz. of salt pork; on one day, 6 oz. of beef; and on one day, 6 oz. of smoked bacon; altogether in the week, 44 oz. of meat are issued; and in addition, 1 oz. of butter or fat.

There are also issued per week :—$24\frac{1}{2}$ ounces of biscuit, 147 ounces of flour for bread, $29\frac{1}{2}$ ounces of flour for cooking, $5\frac{1}{2}$ ounces of pickled cabbage (sour kraut), 9 ounces of potatoes, $5\frac{1}{2}$ ounces of pease, and 5 ounces of barley.

Wine, brandy, and beer are also given.

For the calculation of the nitrogenous substances in meat, Artmann, the Austrian surgeon, has been followed; but as he takes the nitrogenous consti-

* 25 per cent. is lost in boiling and peeling; besides, smaller potatoes than the English kind are served out, occasioning still more waste.

tuents of meat as 20 per cent., and the fat as 10 per cent., the proportion of these two constituents is rated too high.

RUSSIAN SOLDIER.*

There are 196 *Meat days and* 169 *Fast days in the Year.*

	Meat days.	Fast days.	
	Meat with Schtschi and Gruel, 196 days.	Schtschi and Gruel, 117 days.	Peas and Gruel, 52 days.
Meat,	7 oz. Eng.	...	...
Bread (Rye),	42 ,,	42 oz.	42 oz.
Sour kraut (and sliced cabbage),	14·5 fl. oz.	14·5 fl. oz.	...
Chervil (*Cerefolium*, an aromatic herb, fresh),	...	1·1 oz.	...
Peas,	...	...	2·33 fl. oz.
Oats (unhusked),	0·5 fl. oz.	0·7 fl. oz.	0·28 fl. oz.
Flour,	0·7 fl. oz.	0·7 fl. oz.	...
Onions,	0·2 fl. oz.	0·3 fl. oz.	0·5 fl. oz.
Pepper,	3 grs.	3 grs.	3 grs.
Bay leaves,	3 grs.	3 grs.	3 grs.
Vegetable oil,	...	$\frac{1}{4}$ fl. oz.	...
Water,	70 fl. oz.	70 fl. oz.	70 fl. oz.
Butter,	0·6 oz.	...	...
Lard,	...	0·5 oz.	0·5 oz.
Salt,	1·86 oz.	1·86 oz.	1·86 oz.
Buckwheat,	1·87 fl. oz.	1·87 fl. oz.	1·87 fl. oz.

On the march, 1$\frac{3}{4}$ ℔ biscuit (24$\frac{1}{2}$ English oz.) instead of bread. Brandy only on rare occasions, calculated at 135 fluid ounces per year (in 5 oz. rations).

Hindu diet.—The Hindu diet consists of some of the millets (cholum, raggee, cumboo, see Millets), rice, leguminosæ (*Cajanus indicus*), with green vegetables, oil, and spices. If any kind of diet of this sort has to be calculated, it can be readily done by means of the analysis of the usual foods given further on. For example, a Hindu prisoner at labour in Bengal, receives, under Dr Mouat's dietary,† the following diet during his working days :—

	Total. oz.	Water. oz.	Album. oz.	Fat. oz.	Starches. oz.	Salt. oz.
Rice,	20	2	1	·16	16·74	·1
Dholl (a pea, *Cajanus indicus*),	4·25	·4	·9	·08	2·75	·12
Vegetables (reckoned as cabbage),	6	5·46	·12	·03	·34	·04
Oil,	·33	...	...	·33	...	...
Salt,	·33	...	...	...	...	·33
Spices,	·33	...	...	...	...	...

In some Bengal prisons, 2 ounces of fish or flesh appear to be also given.

* From Dr Oscar Heyfelder's "The Russian Camp at Krasnoe Selo," German edition. 1868. The gruel is made of boiled buckwheat, &c. Schtschi is made of soup and sour kraut well boiled together. The amount of bread seems large, but it may be watery.

† See Mouat's elaborate report "On the Diet of Bengal Prisoners," Government Return, 1860, p. 49. The chittack is reckoned as the bazaar chittack—viz., = ·1283 ℔, or nearly 2 ounces avoir.

SECTION III.

FOOD IN SICKNESS.

This subject belongs to the practice of medicine, and cannot be treated in a work on Hygiene. A few words may, however, be said.

A man in health in perfect rest requires a certain amount of food to maintain the internal work of the body, such as the work of the heart, of the respiratory muscles, the movements of the stomach and intestines, the nervous currents, &c., and the animal heat. In sickness, he also requires this; and if he cannot take it and digest it, he will feed on his own body, and it will be only a question of time when the internal mechanical work will fail. The food which he must take ought as a rule to be composed of each of the four classes, for there is no reason to think the sick body is otherwise nourished than the healthy. If our calculations are right, every sick adult man ought to take, in order to keep his heart and lungs in just sufficient action to keep him alive, 2 ounces of dry albuminate (= 138 grains of nitrogen), $\frac{1}{2}$ ounce of fat, and 12 ounces of starches (= in all nearly 3000 grains of carbon) and salts. The effect of keeping patients on a still smaller diet is, in most cases, to largely increase the mortality. There may, of course, be cases in which greater abstinence may be desirable, and the patient be left to exist for some days on materials derived from his own body, but such cases are certainly rare. In the majority of cases, a larger diet than the minimum is absolutely necessary—a diet perhaps equal, or nearly so, to that of health; and some physicians are even inclined to give more than in health.

But this is probably running to the other extreme, for if food be not digested and absorbed, or if it be imperfectly prepared in the alimentary canal, it must do harm. Certainly, the giving of food in sickness is an art requiring great care and study; and I venture to think the plan followed by some physicians of ordering very large quantities of food, and at very short intervals, with an idea of giving "support," is based on a questionable theory. The appetite and instincts of the sick are often the only guide.

The form in which food is given to the sick is only less important than the quantity. The nervous currents and muscular movements, the powers and physical state of the heart and circulation, and the consequent passing out of the digestive fluid, and the transit inward of the food, are all altered and generally lessened. The digestibility of the food becomes then a matter of the greatest moment. The degree of liquidity and dilution, or of concentration and solidity, the bulk, the softness and minuteness of division, &c., are all matters requiring consideration in every case of sickness.

The effects of alteration in the amount of the several alimentary principles in the treatment of disease is a subject of great interest, on which we have little information at present. The nitrogenous tissues or the fat can be wasted almost at will, by withholding albuminates or starches. Nutritive formation can be increased by albuminates and fats, if exercise of muscular organs can be also secured. Destruction of the nitrogenous tissues, or in other words oxidation, can be to some extent controlled by starches and by fats, and deficient oxidation can be increased by exercise and albuminates, and possibly by alkalies. The action of the liver cells in producing bile is augmented by albuminates—lessened by much fat. The salts evidently play important parts, and iron is used for the nourishment of the red blood-cells, potassium chloride (not in excessive quantity) for the muscles, calcium phosphate for cell growth generally (?), and calcium and magnesium salts for bone;

the alkaline salts of the vegetable acids and lactic acid are important for the prevention or removal of the peculiar state we term scurvy.

With respect to different articles of food, a pure vegetable diet increases the water of the body (Bischoff and Voit), while an exclusive meat diet lessens it.

It cannot be said that we are yet in a position to practically use the physiological facts now being gradually discovered, but there can be little doubt that the dietetic treatment of disease is destined to be the great work of the future. In the meantime, until our knowledge is more advanced, it may be a good rule in disease to consider the diet of health, if it can be taken by the patient, to be the best adapted for nutrition in disease, and to deviate from it only on some intelligible and certain ground.

Fixed scales of diet for sick must be used in hospitals for convenience; but the innumerable wants of the sick can never be compressed into three or four, or even ten or twelve rigid scales; and as the treatment by diet is better understood, the fixed diet tables will gradually become mere outlines, which will be filled up by orders for each special case.

In the army, in order to facilitate work, a very elaborate system of diet tables is in use, which is intended to avoid, as far as possible, the employment of extras. There are altogether ten diets—tea, spoon, beef-tea, milk, low, chicken, half, fish, roast, entire. The amount is given in the Medical Regulations. The following table shows the quantity in the chief diets:—

*Nutritive Value of Military Hospital Diets, as fixed by Regulation.**

Name of Diet.	Amount of the Different Constituents in Ounces and Tenths of Ounces.						
	Albuminates.	Fats.	Carbo-hydrates.	Salts.	Water-free Weight.	Water.	Total Weight.
Tea Diet	·880	·342	6·648	·153	8·023	8·477	17
Spoon Diet	·960	·342	8·288	·173	9·763	8·737	18¾
Milk "	3·620	2·446	12·517	·557	19·140	57·850	77
Beef-tea "†	2·400	1·074	7·651	·828	11·953	16·047	28¼
Low "†	3·503	2·792	11·531	1·004	18·845	31·450	49 11/20
Half "‡	3·072	2·102	12·966	1·306	19·446	27·607	47¾
Entire "§	3·792	2·446	14·838	1·450	22·526	36·267	59¼
Chicken "	3·411	1·554	10·603	1·279	16·847	18·403	35½
Fish "	3·134	2·384	12·475	1·394	19·387	24·863	44½

SECTION IV.

DISEASES CONNECTED WITH FOOD.

So great is the influence of food on health, that some writers have reduced hygiene almost to a branch of dietetics. Happiness, as well as health, is considered to be insured or imperilled by a good or improper diet, and high moral considerations are supposed to be involved in the due performance of digestion. If there is some exaggeration in this, there is much truth; and doubtless, of all the agencies which affect nutrition, this is the most important.

* The amounts of the different articles are given in the Medical Regulations. The total weight does not always correspond to the other numbers, as tea, &c., is omitted.

† As soup is only given, and not the entire meat, the amount of the albuminates is too high.

‡ Roast half nearly the same.

§ Varied diet almost the same.

The diseases connected with food form, probably, the most numerous order which proceeds from a single class of causes; and so important are they, that a review of them is equivalent to a discussion on diseases of nutrition generally. It is of course impossible to do more here than outline so large a topic.

Diseases may be produced by alterations (excess or deficiency) in quantity; by imperfect conditions of digestibility, and by special characters of quality.

SUB-SECTION I.—ALTERATIONS IN QUANTITY.

1. *Excess of Food.*—In some cases, food is taken in such excess, that it is not absorbed; it then undergoes chemical changes in the alimentary canal, and at last putrefies; quantities of gas (carbonic acid and sulphuretted hydrogen) are formed. As much as 30 ℔ of a half-putrid mass have been got rid of by purgatives.* Dyspepsia, constipation, and irritation, causing diarrhœa, which does not always empty the bowels, are produced. Sometimes some of the putrid substances are absorbed, as there are signs of evident poisoning of the blood, a febrile condition, torpor and heaviness, fœtor of the breath, and sometimes possibly even jaundice. It was, no doubt, cases of this kind which led to the routine practice of giving purgatives; and as this condition, in a moderate degree, is not uncommon, the use of purgatives will probably never be discontinued.

The excess of food may be absorbed. The amount of absorption of the different alimentary principles is not precisely known. Dogs can digest an immense quantity of meat, and especially if they are fed often; and not simply largely, once or twice a-day. In men, also, much meat and albuminous matter can be digested,† though it is by no means uncommon, in large meat-eaters, to find much muscular fibre in the fæces. Still, enough can be taken, not merely to give a large excess of nitrogen, but even to supply carbon in sufficient quantity for the wants of the system.

There is certainly a limit to the digestion of starch (though sugar, however, is absorbed in large amount), as after a very large meal much starch passes unaltered. This is also the case with fat; and if large quantities are given, much passes by the bowels. But in all cases, habit probably much affects the degree of digestive power; and the continued use of certain articles of diet leads to an increased formation of the fluids which digest them.

When excess of albuminates continually passes into the system, congestions and enlargements of the liver, and probably other organs, and a general state of plethora, are produced. If exercise is not taken at the same time, there is a disproportion between the absorbed oxygen and the absorbed albuminates, which must lead to imperfect oxidation, and therefore to retention in the body of some substances, or to irritation of the eliminating organs by the passage through them of products less highly elaborated than those they are adapted to remove.

Although not completely proved, it is highly probable that gouty affections arise partly in this way, partly probably from the use of liquids which delay metamorphosis, and therefore lead to the same result as increased ingestion, and in some degree also from the use of indigestible articles of food.

Very often large meat-eaters are not gouty, and do not appear in any way over-fed. In this case, either a great amount of exercise is taken, or, as is

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* A good case of this kind is recorded by Routh (Fæcal Fermentation, p. 19). Some convicts in Australia received from 7¼ to 7½ ℔ of food daily. Obstinate constipation, dyspepsia, diarrhœa, skin diseases, and ophthalmia were produced. Purgatives brought away large quantities of half-putrid masses.

† Jones's, and especially Hammond's experiments, "Experimental Researches," 1857, p. 20.

often the case in these persons, the meat is not absorbed, owing frequently to imperfect mastication.

A great excess of albuminates, without other food, produces in a short time (five days—Hammond) marked febrile symptoms, malaise, and diarrhœa; and if persevered in, albumen appears in the urine. Ranke has attributed the depression especially to the effect of the salts of the meat.

Excess of starches and of fats delays the metamorphosis of the nitrogenous tissues, and produces excess of fat. Sometimes acidity and flatulence are caused by the use of much starch. It is not understood if profounder diseases follow the excessive use of starches unless decided corpulence is produced, when the muscular fibres of the heart and of many voluntary muscles lessen in size, and the consequences of enfeebled heart's action are produced. When an excessive quantity of starch is used to replace albuminates, in physiological experiments, the condition becomes of course a complex one.

If an excess of starch be taken under any circumstances, much passes into the fæces, and the urine often becomes saccharine.

There may be also excess of food in a given time; that is, meals too frequently repeated, though the absolute quantity in twenty-four hours may not be too great.

2. *Deficiency of Food.*—The long catalogue of effects produced by famine is but too well known, and it is unnecessary to repeat it here. But the effects produced by deficiency in any one of the four great classes of aliments, the other classes being in normal amount, have not yet been perfectly studied.

The complete deprivation of albuminates, without lessening of the other classes, begins to produce marked effects in from four to five days. There is great loss of muscular strength, often mental debility, some feverish and dyspeptic symptoms. Then follow anæmia and great prostration. The elimination of nitrogen in the form of urea greatly lessens, while the uric acid diminishes in a less degree. If starch be largely supplied, the weight of the body does not lessen for seven or eight days (Hammond).

If the deprivation of albuminates be less complete (70 to 100 grains of nitrogen being given daily), the body lessens in activity, and passes into more or less of an adynamic condition, which predisposes to the attacks of all the specific diseases (especially of malarious affections and typhus), and of pneumonia, and modifies the course of some of these diseases, as, for instance, of typhoid, which runs its course with less elevation of temperature than usual, and with less or with no excess of ureal excretion.

The deprivation of starches can be borne for a long time if fat be given, but if both fat and starch are excluded, though albuminates be supplied, illness is produced in a few days. Nor is it difficult to explain this: as albumen contains 53·5 per cent. of carbon and 15·5 per cent. of nitrogen, to supply 3500 grains of carbon no less than 1014 grains of nitrogen must be introduced, a quantity three times as great as the system can easily assimilate, unless enormous exertion be taken, and then the quantity of carbon becomes insufficient.

Men can be fed on meat for a long time, as a good deal of fat is then introduced, and if the meat be fresh (and raw?), scurvy is not readily induced.

The deprivation of fat does not appear to be well borne, even if starches be given; but the exact effects are not, I believe, known. The great remedial effects produced by giving fat in many of the diseases of obscure mal-nutrition, prove that the partial deprivation of fat is both more common and more serious than is supposed. The deprivation of the salts is also evidently attended with marked results which are worthy of more attention than they have yet received.

Bad effects are also produced if the intervals between meals are too long: this is a matter in which there is great individual difference, and need not be further referred to.

Sub-Section II.—Conditions of Digestibility and Assimilation.

A great number of diseases are produced, not by alterations in quantity, or by imperfections in quality of the raw food, but by conditions of indigestibility, either dependent on physical or chemical conditions of the food itself, or of the digestive fluids. To some persons certain foods are indigestible at all times, or at particular times. Indigestibility leads to retention, and then to the results of retention, viz., chemical changes and putrefaction going on in the stomach and bowels under the influence of warmth, moisture, and air. Then irritation is produced, and dyspepsia, diarrhœa, or dysentery, are caused.

Indigestibility extends, however, farther than this. There is some reason for thinking that the albuminates sometimes pass into the circulation less properly prepared than usual to undergo the action of the liver, and that they therefore produce irritation of that organ, and passing into the blood in some unassimilable state, produce irritation of the skin or kidneys. Sometimes, indeed, albumen appears in the urine, as if it had circulated like a foreign body in the blood. Such conditions are usually allied to some evident error in primary digestion, but occasionally are not obviously accompanied by any gastric disorder. Whether there is any similar imperfection in the digestion of starch or fat is not at present known.

Sub-Section III.—Conditions of Quality.

Altered quality of what is otherwise good food produces a great number of diseases. Most of these are referred to under the headings of the different articles of food, and the subject is merely introduced here to complete the general sketch of the production of disease from food.

In inquiring, then, into the effects of food, the following appears to be the best order of procedure:—

1. Is the food excessive or deficient in quantity as a whole, or in any of the primary classes of aliments?
2. Are the different articles digestible and assimilable, or from some cause inherent in the food or proper to the individual, is there difficulty in primary digestion or want of proper assimilation?
3. Is the quality of the food altered either before or after cooking?

CHAPTER VI.

QUALITY, CHOICE, AND COOKING OF FOOD, AND DISEASES ATTRIBUTABLE TO IMPROPER QUALITY.

SECTION I.

MEAT.

The advantages of meat as a diet are—its large amount of nitrogenous substance, the union of this with much fat, the presence of important salts (viz., chloride of potassium, phosphate of potash, carbonate of potash, or a salt-forming carbonate in incineration), and iron. It is also easily cooked, and is very digestible; it is probably more easily assimilated than any vegetable, and there is a much more rapid metamorphosis of tissue in carnivorous animals than in vegetable feeders. Whether the use of large quantities of meat increases the bodily strength or the mental faculties more than other kinds of nitrogenous food, is uncertain. The great disadvantage of meat is the want of starch.

The composition of fresh and salt meat has been already given (pages 165 and 166); but the annexed table will supply further details :—

Composition of Fresh Beef. (Moleschott—Mean of all the Continental Analyses.)

Water,	73·4
Soluble albumen and hæmatin,	2·25
Insoluble albuminous substances,	15·2
Gelatinous substances,	3·3
Fat,*	2·87
Extractive matters,	1·38
Kreatin,	0·068
Ash,	1·6

The composition of the ash has already been given (page 167).

It is worthy, however, of remark, that Stölzel † found 8·9 per cent. of carbonic acid in 100 of ash, which indicates probably lactic acid. Are the anti-scorbutic properties of fresh and raw (?) meat connected with this acid, and is it destroyed by cooking? More than one-third of the ash is composed of phosphoric acid. It is alkaline.

Beef, mutton, and pork form the chief meats eaten by the soldier.

In time of peace he only receives fresh meat, beef and mutton, and more seldom pork; in time of war he has salt beef and salt pork. The meat is supplied by contractors, or is, at some stations, furnished by the commissariat, who have their own slaughter-houses.

The salt meat is prepared in the usual way, but it is possible that Professor Morgan's improved process will supersede the old plan. Instead of

* The amount of fat in this analysis is certainly too low.
† Liebig's Annalen, band lxxvii. p. 256.

cutting the meat into small masses, and placing it in brine, Professor Morgan, immediately after death, opens the thorax, inserts a pipe into the left ventricle, and connects the pipe, by an india-rubber tube, with a tank of brine placed at a few feet elevation, and injects the vessels. After the blood has been driven out through the right auricle, the exit is closed, and the pressure forces the brine into the smallest ramifications of the vessels. The process is finished in ten to twenty minutes; the meat is then cut up, dried, if necessary, in a hot-air chamber, and packed in charcoal. The injected fluid is composed of 1 gallon of brine to the cwt., $\frac{1}{4}$ to $\frac{1}{2}$ ℔ of nitre, 2 ℔ of sugar, a little spice, salt, and $\frac{1}{2}$ oz. of phosphoric acid, which serves more completely to retain the albumen, and also adds a little phosphoric acid. The brine can be used hot. This is an excellent plan, but the meat is too salt.

The medical officer may be called on to see the animals during life, or to examine the meat.

Sub-Section I.—Inspection of Animals.

Animals should be inspected twenty-four hours before being killed.* In this country killing is done twenty-four or forty-eight hours before the meat is issued; in the tropics only ten or twelve hours previously.

Animals should be well grown, well nourished, and neither too young nor too old. The flesh of young animals is less rich in salts, fat, and syntonin, and also loses much weight (40 to 70 per cent.) in cooking.

Weight.—An ox should weigh not less than 600 ℔, and will range from this to 1200 ℔. The French rules fix the minimum at 250 kilogrammes (= 550 ℔ av.). The mean weight in France is 350 kilogrammes (= 770 ℔ av.). A cow may weigh a few pounds less; a good fat cow will weigh from 700 to 740 ℔. A heifer should weigh 350 to 400 ℔. The French rules fix the minimum of the cow's weight at 160 kilogrammes (= 352 ℔). The mean weight of cows in France is 230 kilogrammes (= 506 ℔).

There are several methods of determining the weight; the one most commonly used in this country is to measure the length of the trunk from just in front of the scapulæ to the root of the tail, and the girth or circumference just behind the scapulæ; then multiply girth by 0·08, and the product by the length, the dimensions in cubic feet are obtained; each cubic foot is supposed to weigh 42 ℔ avoirdupois. The formula is $(C \times \cdot 08) \times L \times 42$. An ox or cow gives about 60 per cent. of meat, exclusive of the head, feet, liver, lungs, and spleen, &c.†

A full-grown sheep will weigh from 60 to 90 ℔, but the difference in different breeds is very great. It also yields about 60 per cent. of available food.

A full-grown pig weighs from 100 to 180 ℔ or more, and yields about 75 to 80 per cent. of available food.

Age.—The age of the *ox and cow* should be from three to eight years; the age is told chiefly by the teeth, and less perfectly by the horns. The temporary teeth are in part through at birth, and all the incisors are through in twenty days; the first, second, and third pairs of temporary molars are through in thirty days; the teeth are grown large enough to touch each other by the sixth month; they gradually wear and fall in eighteen months; the fourth

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* Every contract should have a clause giving officers the power of inspection.

† The animal is divided into carcass and offal; the former includes the whole of the skeleton (except the head and feet), with the muscles, membranes, vessels, and fat, and the kidneys and fat surrounding them. The offal includes the head, feet, skin, and all internal organs, except the kidneys.

permanent molars are through at the fourth month; the fifth at the fifteenth; the sixth at two years. The temporary teeth begin to fall at twenty-one months, and are entirely replaced by the thirty-ninth to the forty-fifth month; the order being—central pair of incisors gone at twenty-one months; second pair of incisors at twenty-seven months; first and second temporary molars at thirty months; third temporary molars at thirty months to three years; third and fourth temporary incisors at thirty-three months to three years. The development is quite complete at from five to six years. At that time the border of the incisors has been worn away a little below the level of the grinders. At six years the first grinders are beginning to wear, and are on a level with the incisors. At eight years the wear of the first grinders is very apparent. At ten or eleven years the used surface of the teeth begin to bear a square mark surrounded with a white line; and this is pronounced on all the teeth by the twelfth year; between the twelfth and fourteenth year this mark takes a round form.

The rings on the horns are less useful as guides. At ten or twelve months the first ring appears; at twenty months to two years the second; at thirty to thirty-six months the third ring; at forty to forty-six months the fourth ring; at fifty-four to sixty months the fifth ring, and so on. But at the fifth year, the three first rings are indistinguishable, and at the eighth year all the rings. Besides, the dealers file the horns.

In the sheep, the temporary teeth begin to appear in the first week, and fill the mouth at three months; they are gradually worn and fall about fifteen or eighteen months. The fourth permanent grinders appear at three months, and the fifth pair at twenty to twenty-seven months. A common rule is "two broad teeth every year." The wear of the teeth begins to be marked about six years.

The age of the pig is known up to three years by the teeth; after that there is no certainty. The temporary teeth are complete in three or four months; about the sixth month, the premolars, between the tusks and the first pair of molars, appear; in six or ten months the tusks and posterior incisors are replaced; in twelve months to two years the other incisors; the fourth permanent molars appear at six months; the fifth pair at ten months; and the sixth and last molars at eighteen months.

Condition and Health.—There ought to be a proper amount of fat, which is best felt on the false ribs and the tuberosities of the ischium, and the line of the belly from the sternum to the pelvis; the flesh should be tolerably firm and elastic; the skin should be supple.

As showing health, we should look to the general ease of movements, the quick bright eyes, the nasal mucous membrane red, moist, and healthy-looking; the tongue not hanging; the respiration regular, easy; the expired air without odour; the circulation tranquil; the excreta natural in appearance.

When sick, the coat is rough or standing; the nostrils dry, or covered with foam; the eyes heavy; the tongue protruded; the respiration difficult; movements slow and difficult; there may be diarrhœa; or scanty or bloody urine, &c. In the cow the teats are hot.

The diseases of cattle which the medical officer should watch for are—

1. *Epidemic Pleuro-pneumonia* (a lung disease).—Not easily recognised at first, but with marked lung symptoms after a few days.
2. *Foot-and-Mouth Disease* (murrain, aphtha, or eczema epizootica).—At once recognised by the examination of the mouth, feet, and teats.
3. *Cattle Plague* (typhus contagiosus, Steppe disease, Rinderpest).—Recognised by the early prostration (hanging of head, drooping of ears), shivering, running from eyes, nose, and mouth, peculiar condition of tongue and lips, cessation of rumination, and then by abdominal pain, scouring, &c.

4. *Anthrax* (malignant pustule, carbuncular fever).—If boils and carbuncles form, they are at once recognised; if there is erysipelas, it is called black-quarter, quarter-ill, or blackleg (erysipelas carbunculosum), and is easily seen.
5. *Simple inflammatory affections* of the lungs, bronchitis, and simple pneumonia. All have obvious symptoms.
6. *Dropsical affections* from kidney or heart disease.
7. *Indigestion*, often combined with apoplectic symptoms.

A great number of other diseases attack cattle, which it is not necessary to enumerate. All the above are tolerably easily recognised. The presence of *Tænia mediocanellata* cannot, to my knowledge, be detected before death.

The diseases of sheep are similar to those of cattle; they suffer also in certain cases from splenic apoplexy or "braxy," which is considered by Professor Gamgee to be a kind of anthrax, and is said to kill 50 per cent. of all young sheep that die in Scotland; the animals have a "peculiar look, staggering gait, blood-shot eyes, rapid breathing, full and frequent pulse, scanty secretions, and great heat of the body." *

The smallpox in sheep (variola ovina, *clavelée* of the French) is easily known by the flea-bitten appearance of the skin in the early stage, and by the rapid appearance of nodules or papulæ and vesicles.

The sheep is also subject to black-quarter (erysipelas carbunculosum); one limb is affected; and the limp of the animal, the fever, and the rapid swelling of the limb, are sufficient diagnostic marks.

The sheep, of course, may suffer from acute lung affection, scouring, red water (hæmaturia), and many other diseases. Of the chronic lung affections, one of the most important is the so-called "phthisis," which is produced by the ova of the *Strongylus filaria*. This entozoon has not, I believe, been yet found in the muscles, and the meat is said to be good. The rot in sheep (fluke disease) is caused by the presence of the *Distoma hepaticum* in large numbers in the liver, and sometimes by other parasites. The principal symptoms are dulness, sluggishness, followed by rapid wasting and pallor of the mucous membrane, diarrhœa, yellowness of the eyes, falling of the hair, and dropsical swellings. The animal is supposed to take in the Cercaria (the embryotic stage of the distoma) from the herbage. The so-called "gid," "sturdy," or "turnsick," is caused by the development of the *Cœnurus cerebralis* in the brain.

The pig is also attacked by anthrax in different forms; by typhoid, and by hog cholera, which may perhaps be a rapid form of typhoid. The swelling in the first case, and the scouring, fever, and prostration in the second, are sufficient diagnostic marks. In 1864, a severe fever of this kind, with or without scouring, prevailed among the pigs in London.

The so-called measle of the pig is caused by the presence in the muscle of the *Cysticercus cellulosus*. It is detected in the following way:—The "measle trier" throws the pig on its back, draws out and wipes the tongue, and looks and feels for the sublingual vesicles containing the Cysticerci. Sometimes a bit is cut out of the muscle under the tongue, and the Cysticerci are microscopically examined. A small harpoon can be used for this purpose, and gives little pain. Sometimes the Cysticercus can be seen on the conjunctiva, or on the folds of the anus. When the disease is far advanced, the animal is dull, the eyes heavy, appetite bad. These symptoms are, however, not peculiar; there is said to be sometimes tenderness in the groin (Grève), but, according to Delpech, this is very uncertain; a better sign is a certain amount of

* Fifth Report of the Medical Officer to the Privy Council, p. 222.

swelling of the shoulder, which causes a sort of constriction of the neck, and somewhat impedes the movements of the animal (Delpech). The presence of the *Trichina spiralis* is indetectable before death, unless it be also found in the muscles under the tongue.

Sub-Section II.—Inspection of Dead Meat.

1. *Fresh Meat.*

Meat should be inspected, in temperate climates, twenty-four hours after being killed; in the tropics, earlier.

The following points must be attended to:—

(*a.*) *Quantity of Bone.*—In lean animals, the bone is relatively in too great proportion; taking the whole animal, 20 per cent. should be allowed.

(*b.*) *Quantity and Character of the Fat.*—It should be sufficient, yet not excessive, else the relative proportion of albuminous food is too low; it should be firm, healthy looking, not too yellow; without hæmorrhage at any point. The kind of feeding has an effect on the colour of the fat; some oil-cakes give a marked yellow colour.

Professor Gamgee states that pigs fed on flesh have a peculiarly soft diffluent fat, and omit a strong odour from their bodies. The same authority tells us that the butchers will rub melted fat over the carcass of thin and diseased animals, to give the glossy look of health.

(*c.*) *Condition of the Flesh.*—The muscles should be firm, and yet elastic; not tough; the pale moist muscle marks the young animal, the dark-coloured the old one; the muscular fasciculi are larger and coarser in bulls than oxen. When good meat is placed on a white plate, a little reddish juice frequently flows out after some hours. There should be no lividity or marbling on cutting across some of the muscles; the interior of the muscle should be of the same characters, or a little paler; there should be no softening, mucilaginous fluid, or pus, in the intermuscular cellular tissue. This is an important point, which should be closely looked to. The intermuscular cellular tissue becomes soft, and tears easily when stretched in commencing putrefaction.

The degree of freshness of meat in commencing putrefaction is judged of by the colour, which becomes paler; by the odour, which becomes at an early stage different from the not unpleasant odour of fresh meat, and by the consistence. Afterwards, the signs are marked; the odour is disagreeable, and the colour begins to turn greenish. It is a good plan to push a clean knife into the flesh up to its hilt. In good meat the resistance is uniform; in putrefying meat, some parts are softer than others. The smell of the knife is also a good test. Cysticerci and Trichinæ should be looked for. (See below).

(*d.*) *Condition of the Marrow.*—In temperate climates the marrow of the hind legs is solid, twenty-four hours after killing; it is of a light rosy red. If it is soft, brownish, or with black points, the animal has been sick, or putrefaction is commencing. The marrow of the fore-legs is more diffluent; something like honey—of a light rosy red.

(*e.*) *Condition of Lungs and Liver.*—Both should be looked at, to detect the *Strongylus filaria* in the lungs; the Distoma in the liver; also for the presence of multiple abscesses.

(*f.*) To detect cattle plague, the mouth, stomach, or intestines must be seen; no alterations have as yet been pointed out in the naked-eye appearance of the muscles, though under the microscope they are found to be degenerating like the muscles in human typhoid (Buchanan).

But meat cannot be fully judged of till it has been cooked, so as to see how much it loses in roasting or boiling; whether the fibres cook hard, &c.

In countries where there are goats, the attached foot of the sheep should be sent in for identification.

Decomposing sausages are difficult of detection until the smell alters. Artmann recommends mixing the sausage with a good deal of water, boiling and adding freshly prepared lime-water. Good sausages give only a faint, not unpleasant, ammoniacal smell; bad sausages give a very offensive, peculiar ammoniacal odour.

Microscopic Examination of Meat.

In the flesh of cattle, or of the pig, Cysticerci may be found. They are generally visible to the naked eye as small round bodies; when placed under a microscope with low power, their real nature is seen; they are sometimes so numerous as to cause the flesh to crackle on section. In some countries they are extremely common in cattle, and have been a source of considerable trouble in North-West India. The Cysticercus of the ox produces in man the *Tænia mediocanellata.*

The Trichinæ may be present in the flesh of the pig; if encapsuled, they will be seen with the naked eye as small round specks; but very often a microscope is necessary. A power of 50 to 100 diameters is sufficient. The best plan is to take a thin slice of flesh; put it into liquor potassæ (1 part to 8 of water), and let it stand for a few minutes till the muscle becomes clear; it must not be left too long, otherwise the Trichinæ will be destroyed. The white specks come out clearly, and the worm will be seen coiled up. If the capsule is too dense to allow the worm to be seen, a drop or too of weak hydrochloric acid should be added. The parts most likely to be infected are said to be the muscular part of the diaphragm, the intercostal muscles, and the muscles of the eye and jaw.* In diagnosing Trichinæ, the coiled worm should be distinctly seen.

The so-called Psorospermia, or Rainey's capsules, must not be mistaken for the Trichinæ, nor indeed with care is error possible. These are little, almost transparent, bodies, found in the flesh of oxen, sheep, and pigs. They are in shape oval, spindle-shaped, or sometimes one end is pointed and the other rounded, or they are kidney-shaped. The investing membrane exhibits delicate markings, caused by a linear arrangement of minute hair-like fibres, which Mr Rainey† states increase in size as the animal gets older. They sometimes are pointed, and the appearance under a high power (1000 diameters) is as if the investment consisted of very delicate, transparent, conical hairs, terminating in pointed processes.‡ The contents of the cysts consist of granular matter, the granules or particles of which when mature are oval, and which adhere together, so as to form indistinct divisions of the entire mass. The length varies from $\frac{1}{300}$ to $\frac{1}{4}$ of an inch. They are usually narrow; they lie within the sarcolemma, and appear often not to irritate the muscle.

Till the present time no injurious effect has been known to be produced on men by these bodies, notwithstanding their enormous quantities in the flesh of domestic animals, nor have they been discovered in the muscles of men. But in pigs these bodies sometimes produce decided illness; besides general signs of illness, there are two invariable symptoms, viz., paralysis of the hind legs, and a spotty or nodular eruption.§ In sheep they have been known to affect the muscles of the gullet, and produce abscesses, or what may be called so, viz., swellings sometimes as large as a nut, and containing a milky

* Lion—Comp. des Sanit. Pol. p. 171.
† Phil. Trans. 1857.
‡ Beale, in Third Report of the Cattle Plague Commission, Appendix.
§ Virchow's Archiv, band xxxviii. p. 355.

purulent-looking fluid, with myriads of these capsules in it. Sheep affected in this way often die suddenly.*

It is by no means improbable that some effect on man may be hereafter discovered to be produced.

The bodies which have been also termed Psorospermia, which have been found in the liver of the rabbit, and other parts, and in the liver of man, and which have been described by many observers in different terms,† may possibly be found in other animals, as they have been seen in the dog by Virchow. They are quite different from Rainey's corpuscles; they are oval or rounded bodies, at first with granular contents, and then with aggregations of granules into three or four rounded bodies, on which something like a nucleolus is seen. They have often been mistaken for pus cells.

Some other bodies occur in the flesh of pigs, the nature of which is not yet known. Wiederhold‡ describes a case in which little white specks, with all the appearance at first of encapsuled Trichinæ, could not be proved to be so, and their real nature was quite obscure.

Virchow has described little concretions in the flesh of the pig, which seemed to be composed of guanin;§ these were also at first taken for encapsuled Trichinæ.

Roloff || has described little hard round nodules in the flesh of the pig; some seem very small, others as large as the head of a pin, with little prolongations running to the surrounding muscular fibres to which they are attached. On the outside of these bodies are bundles of fine hairs or needles, sometimes arranged quite in a feather-like form. The bodies have a great resemblance to the guanin bodies of Virchow, but the needles are not crystalline. Roloff puts the question if these bodies are of post-mortem origin.

It is hardly necessary to state that in cutting across meat, small bits of tendons or fascia, sometimes very like a little cyst, will be found; but common care will prevent a mistake.

2. *Salt Meat.*

It is not at all easy to judge of salt meat, and the test of cooking must often be employed. The following points should be attended to :—

(*a.*) *The salting has been well done, but the parts inferior.*—This is at once detected by taking out a good number of pieces; those at the bottom of the cask should be looked at, as well as those at the top.

(*b.*) *The salting well done, and the parts good, but the meat old.*—Here the extreme hardness and toughness, and shrivelling of the meat, must guide us. It would be desirable to have the year of salting placed on the cask of salt beef or pork.

(*c.*) *The salting well done, but the meat bad.*—If the meat has partially putrefied, no salting will entirely remove its softness; and even there may be putrefactive odour, or greenish colour. A slight amount of decomposition is arrested by the salt, and is probably indetectable. Cysticerci are not killed by salting, and can be detected. Measly pigs are said to salt badly, but Mr Gamgee informs me this is not the case.

(*d.*) *The salting badly done, either from haste or bad brine.*—In both cases signs of putrefaction can be detected; the meat is paler than it should be; often slightly greenish in colour, and with a peculiar odour.

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* Leisering, in Virchow's Archiv, band xxxvii. p. 431.

† Leuckardt, Die Menschl. Paras. band i. p. 740; and Stieda, Virchow's Archiv, band xxxii. p. 132. Roloff, Virchow's Archiv, band xliii. p. 512.

‡ Virchow's Archiv, band xxxiii. p. 549.

§ Ibid., band xxxv. 358.

|| Ibid., band xliii. p. 524.

It should be remembered that brine is sometimes poisonous; this occurs in cases where the brine has been used several times; a large quantity of animal substance passes into it, and appears to decompose. The special poisonous agent has not been isolated.

Sub-Section III.—Diseases arising from altered Quality of Meat.

A very considerable quantity of meat from diseased animals is brought into the market. Professor Gamgee has estimated it at one-fifth, but the amount is uncertain.

Instances are not at all uncommon in which persons, after partaking of butcher's meat, have been attacked with serious gastro-intestinal symptoms (vomiting, diarrhœa, and even cramp), followed in some cases by severe febrile symptoms; the whole complex of symptoms somewhat resembles cholera at first, and afterwards typhoid fever. The meat has been often analysed, for the purpose of detecting poison, but none has been found.* In the records of these cases, the kind of meat, the part used, and the origin from a diseased animal, are not stated, and, in some cases, it may be conjectured that the cooking, and not the meat, was in fault. Still, the instances are becoming numerous, and are increasing every day, as attention is directed to the subject. We should conclude from general principles, that as all diseases must affect the composition of flesh, and as the composition of our own bodies is inextricably blended with the composition of the substances we eat, it must be of the greatest importance for health to have these substances as pure as possible. Animal poisons may indeed be neutralised or destroyed by the processes of cooking and digestion, but the composition of muscle must exert an influence on the composition of our own nitrogenous tissues which no preparation or digestion can remove.

On looking through the literature of the subject, however, we find less evidence than might be expected. I cannot but believe this to be, in part, owing to imperfect observation, especially when we think for how long a time the Trichina disease has been overlooked.

1. *The flesh of healthy animals may produce Poisonous Symptoms.*—This is the case with certain kinds of fish, especially in the tropical seas. There is no evidence that the animal is diseased, and the flesh is not decomposed; it produces, however, violent symptoms of two kinds—gastro-intestinal irritation, and severe ataxic nervous symptoms, with great depression and algidity. The little herring (*Clupea harengo minor*), the silver-fish (*Zeus gallus*), the pilchard, the white flat-fish, and several others, have been known to have these effects.† In some cases, though not in all, the poison is developed during the breeding time. Oysters (even when in season) and mussels have been known to produce similar symptoms, without any decomposition. The production of dyspepsia and nettle-rash in some persons from eating shell-fish need scarcely be mentioned.

Among the Mammalia the flesh of the pig sometimes causes diarrhœa—a fact I have had occasion to observe in a regiment in India, and which has been often noticed by others. The flesh is probably affected by the unwholesome garbage on which the pig feeds. Sometimes pork, not obviously diseased,

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* See Professor Gamgee's paper in the Fifth Report of the Medical Officer to the Privy Council, 1863, p. 287. He refers to cases noted by Maclagan, Taylor, Letheby, Dundas Thomson, and Keith.

† A list of more than forty fishes, which are occasionally poisonous, is given by Pappenheim. —*Handb. der Sanitats-Pol.*, band i. p. 395.

has produced choleraic symptoms.* In none of these cases has the poison been isolated.

2. *The flesh of healthy animals when decomposing*, is eaten sometimes without danger; but it occasionally gives rise to gastro-intestinal disorder—vomiting, diarrhœa, and great depression; in some cases severe febrile symptoms occur, which are like typhus, on account of the great cerebral complication. Cooking does not appear entirely to check the decomposition.

It appears to be, in some cases, the acid fluids of cooked meat which promote this alteration.

Sausages and pork-pies sometimes become poisonous from the formation of an as yet unknown substance, which is perhaps of a fatty nature. It is not trimethylamine, amylamine, or phenylamine—these are not poisonous (Schlossberger). The symptoms are severe intestinal irritation, followed rapidly by nervous oppression and collapse. Neither salts nor spices hinder the production of this poison. M. Vanden Corput attributes the poisonous effects of sausages to a fungus, of the nature of a sarcina, or what he terms *Sarcina botulina*.†

Oysters and shell-fish, when decomposing, produce also marked symptoms of the same kind. Rotten fish are used, however, by the Burmese, Siamese, and Chinese, as a sort of condiment, without bad effects.

3. *The fresh and not decomposing flesh of diseased animals* causes in many cases injurious effects. A good deal of difference of opinion, however, exists on this point, and it would seem that a more careful inquiry is necessary. The probability is, that when attention is directed to the subject, the effects of diseased meat will be found to be more considerable than at present believed. At the same time, we must not go beyond the facts as they are at present known to us.

(*a.*) *Accidents.*—The flesh of animals killed on account of accidents may be eaten without injury.

(*b.*) The flesh of over-driven animals is said by Professor Gamgee to contain a poison which often produces eczema on the skin of those who handle it; and eating the flesh is said to "have been attended with bad effects."

(*c.*) *Early stage of Acute Inflammatory Disease.*—The meat is not apparently altered, and it is said that some of the primest meat in the London market is taken from beasts in this condition; it is not known to be injurious, but it has been recommended that the blood should be allowed entirely to flow out of the body, and should not be used in any way.

(*d.*) *Chronic wasting diseases—Phthisis, Dropsy, &c.*—The flesh is pale, cooks badly, and gives rise to sickness and diarrhœa. It also soon begins to decompose, and then causes very severe gastro-intestinal derangement.

(*e.*) *Chronic Nervous Fevers.*—Same as above.

(*f.*) *Epidemic Pleuro-pneumonia of Cattle.*—Much doubt exists as to the effect of this disease on the meat. It is hardly possible that the flesh should not be seriously altered in composition, but it seems certain that a large quantity is daily consumed without apparent injury. I have been informed by two most excellent authorities that the Kaffirs ate their cattle when destroyed by the epidemic lung disease which prevailed at the Cape some years ago, without injury. Both my informants—Staff-surgeon Nicolson and Assistant-surgeon Frank—made very careful inquiries on this point. Dr Livingstone, however, states that the use of such flesh produces carbuncle.

(*g.*) *Anthrax and Malignant Pustule.*—Many of the older authors (Ramazzini, Lancisi, quoted by Levy) mention facts tending to prove the danger of

* Kesteven cites a good case in which twelve persons were affected.—*Med. Times and Gazette*, March 5, 1864.

† Quoted by Letheby, *Chemical News*, Feb. 1869. I have not seen the original paper.

using the flesh of animals affected with malignant pustule. Chaussier also affirmed the same thing, but subsequently modified his opinion considerably. The apparent increase in the number of cases of malignant pustule in men has been ascribed to eating the flesh of animals with this disease, but it is quite as likely that inoculation may have taken place in other ways.

The evidence laid before the Belgian Academy of Medicine led them to believe the flesh of cattle affected with carbuncular fevers to be injurious, and it is not allowed to be sold.

It has been supposed that the outbreaks of boils, which have certainly become more prevalent of late years, are produced by meat of this kind, but the evidence is very imperfect.

Menschel* has also lately recorded a case in which twenty-four persons were seized with malignant pustule, the majority after eating the flesh of beasts suffering from the disease, the others from direct inoculation. Those who ate the flesh were attacked in three to ten days; those who were inoculated, in three to six days. In those who ate the flesh the carbuncle appeared in two cases on the upper arm, in three on the forearm, in nine on the face and head. The gangrenous degeneration rapidly extended. Five died of the twenty-four cases. One woman ate flesh and broth; another ate the same flesh, but threw away the broth. The first was attacked—the second had only diarrhœa. This appears to be the most satisfactory case on record. It is also stated that pigs fed on the flesh got the disease, and that a woman who ate some of the diseased pork was also attacked.

On the other hand, several old authors, and lately Neffel,† assert that the Kirghises constantly eat horses and cattle (either killed or dying spontaneously) affected with malignant pustule without injury.

Parent-Duchâtelet (t. ii. p. 196) quotes a case from Hamel (1737), in which a bull infected three persons who aided in killing it, and a surgeon who opened one of the tumours of a person affected; yet, of more than 100 persons who ate the flesh roasted and boiled, no one experienced the slightest inconvenience, and Parent states that many other cases are known in literature.

Parent-Duchâtelet and Levy (t. ii. p. 661) quote from Morand (1766) an instance in which two bulls communicated malignant pustule to two butchers by inoculation, yet the flesh of the animals was eaten at the "Invalides" without injury. But both these instances are of old date. Pappenheim (*Handb. der Sanitats-Pol.*, band i. p. 587) states (without giving special instances) that there are many cases in which no bad effect resulted from the cooked flesh of charbon—that the peasants of Posen eat such meat with perfect indifference, and believe it is harmless when boiled.

With regard especially to the erysipelas carbunculosus, or black-quarter, as distinguished from malignant pustule (if it is to be so distinguished), Professor Gamgee (Fifth Report of Medical Officer to the Privy Council, p. 290) refers to cases of poisoning, and two deaths mentioned to him by Dr Keith of Aberdeen, caused by eating an animal affected with black-quarter. He also notices an instance which occurred "a number of years ago in Dumfriesshire," when seventeen persons were more or less affected, and at least one died, and states that a number of cases have been related to him by different observers.

The discrepancy of evidence is so great as to lead to the conclusion, that the stage of the disease, or the part eaten, or the mode of cooking, must have

* Preuss. Med. Zeit. 4th June 1862, and Canstatt's Jahresb. 1862, band iv. p. 257.
† Canstatt's Jahresb. for 1860, band ii. p. 137.

great influence, and that a much more careful study than has yet been given to this subject is necessary to clear up these great variations of statement.

(*h.*) *Splenic Apoplexy or Braxy of Sheep.*—Professor Simonds* states that pigs and dogs died in a few hours after eating the flesh of sheep dead of braxy. Professor Gamgee (Privy Council Report, 1863, p. 280) affirms the same thing; but, on the other hand, I am informed by my friend Dr M'Gregor that dogs eat the meat with perfect impunity. The experiments of Alfort (Levy, t. ii. p. 664) have also shown that pigs, dogs, and fowls are not incommoded by this poison, which yet acts violently when swallowed by sheep, goats, or horses. So also Dr Smith states,† that the shepherds in the Highlands of Scotland eat by preference braxy sheep, and are quite healthy. Dr M'Gregor tells me that the flesh of braxy sheep is never cooked until it has been steeped for two months in brine, and then suspended for a time from the kitchen roof. It is preferred to ordinary salt mutton, because it has rather a flavour of game.

(*i.*) *Smallpox of Sheep.*—The flesh has a peculiar nauseous smell, and is pale and moist. It produces sickness and diarrhœa, and sometimes febrile symptoms.

(*j.*) *Foot-and-Mouth Disease* (*Aphtha or Eczema epizootica*).—Levy‡ states that at different times (1834, 1835, 1839) the aphthous disease has prevailed among cattle both at Paris and Lyons, without the sale of the meat being interrupted, or giving rise to bad results. The milk of cows affected with foot-and-mouth disease has been supposed to cause vesicular affection of the mouth in men.§ The evidence seems to me very uncertain. The discharges from the mouth are constantly in the hands of the farm-labourers, who are not very cleanly, and who must constantly convey them to their own mouths, and yet these discharges, so infectious to other cattle, produce no effect on them.

(*k.*) *Cattle Plague* (*Rinderpest, Typhus contagiosus of the French*).—*A priori*, such flesh would be considered highly dangerous, and the Belgian Academy of Medicine so consider it; but there is some strong evidence on the other side. In Strasbourg and in Paris, in 1814, many of the beasts eaten in those cities for several months had Rinderpest, and yet no ill consequences were traced. But it may be questioned whether they were looked for in that careful way they would be at the present day.‖ Some other evidence is stronger: Renault, the director of the Veterinary School at Alfort, made for several years after 1828 many experiments, and asserts that there is no danger from the *cooked* flesh of cattle, pigs, or sheep dead of any contagious disease ("Qu'elle que soit la repugnance bien naturelle que puissent inspirer ces produits."¶) So also during the occurrence of the Rinderpest in England (1865), large quantities of the meat of animals killed in all stages of the disease were eaten without ill effects. In Bohemia also, in 1863, the peasants dug up the animals dead with Rinderpest and ate them without bad results.**

(*l.*) Rabies in the dog and cow produces no bad effects.††

(*m.*) Diseases in the pig, like scarlet fever and pig-typhus, have prevailed lately in London, and the flesh has been eaten. No injury has been proved.‡‡

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* Agricultural Journal, No. 50, p. 232.

† Social Science Trans. for 1863, p. 559.

‡ Traité d'Hygiène, 1857, t. xi. p. 663.

§ Jour. of the Epid. Soc., vol. i. p. 423.

‖ The words of Coze (Parent-Duchâtelet, t. xi. p. 201) are, however, very strong. At Strasbourg he says—"Un millier de bœufs de grande taille, malades pour la plupart au plus haut degré, puisqu'un assez grande nombre ont été égorgés au moment ou ils allerènt expirer, a été consommé, pendant et après le blocus, et cet aliment n'a produit aucune maladie."

¶ Payen, "Des Substances Alimentaires," pp. 30, 31.

** Evidence of Cattle Plague Commission, question 997, and other places.

†† Parent-Duchâtelet, t. ii. p. 197, cites a case of seven mad cows being sold without injury to those who ate the flesh.

‡‡ Letheby, *Chem. News*, Jan 15, 1869.

(*n.*) The *Cysticercus cellulosus* of the pig produces *Tænia solium*, and that of the ox and cow the *Tænia mediocanellata.* These entozoa often arise from eating the raw meat, but neither cooking nor salting are quite preservative, though they may lessen the danger. Smoking appears to kill the Cysticerci, and so, according to Delpech, does a temperature of 212° Fahr.

(*o.*) The *Trichina spiralis* in the pig gives rise to the curious Trichina disease caused by the wanderings of the young Trichinæ. The affection is highly febrile, resembling typhoid or even typhus, or acute tuberculosis, but attended with excessive pains in the limbs, and œdema.* Boils are also sometimes caused. The eating of raw trichiniferous pork is the chief cause, and, as in the case of Cysticerci, the entozoon is not easily killed by cooking or salting. A temperature of 144° to 155° Fahr. kills the free Trichinæ, but the encapsuled Trichinæ may demand a greater heat (Fiedler). During cooking, a temperature which will coagulate the albumen (150° to 155° Fahr.) renders the Trichinæ incapable of propagation, or destroys them. As a practical rule, it may be said that, if the interior of a piece of boiled or roasted pork retains much of the blood-red colour of uncooked meat, the temperature has not been higher than 131° Fahr., and there is still danger. Intense cold and complete decomposition of the meat do not destroy the Trichinæ. Hot smoking, when thoroughly done, does destroy them (Leuckhardt); but the common kinds of smoking, when the heat is often low, do not touch the Trichinæ (Küchenmeister).

(*p.*) The *Echinococcus Disease.*—It is well known that many persons will eat freely of, and even prefer, the liver of the sheep full of flukes. I am not aware that in this country direct evidence has been given of the production of liver echinococcus from this cause, but in Iceland the echinococcus disease, which affects a large number of persons, is derived from sheep and cattle, who in their turn get the disease from the Tænia of the dog (Leared and Krabbe).

(*q.*) Glanders and farcy in horses do not appear to produce any injurious effects on their flesh when eaten as food. Parent-Duchâtelet quotes two instances, in one of which 300 glandered horses were eaten without injury.—(*Hyg. Publ.* t. ii. p. 194. See also Levy, t. ii. pp. 661, 662.)

(*r.*) Medicines, especially antimony, given to the animals in large quantities, have sometimes produced vomiting and diarrhœa. Arsenic, also, is occasionally given, and the flesh may contain enough arsenic to be dangerous.†

In time of peace the duty of the army surgeon is simple. Under the terms of the contract, all sick beasts are necessarily excluded. Without reference, then, to any uncertain questions of hurtfulness, or the reverse, he must object to the use of the flesh of such animals. This is the safe and proper course.

But, in time of war, he may be placed in the dilemma of allowing such meat to be used, or of getting none at all. He should then allow the issue of the meat of all animals, ill with inflammatory and contagious diseases, with the exception of smallpox, and perhaps splenic apoplexy in sheep. But it will be well to take the precautions—1*st*, Of bleeding the animals as thoroughly as possible; 2*d*, Of using only the muscles, and not the organs, as it is quite possible these may be more injurious than the muscles, though there are no decided facts on this point; and, 3*d*, Of seeing that the cooking is thoroughly done. But animals with smallpox, Cysticerci, and Trichinæ, should not be used. If dire necessity compels their use, then the employment of a great

* Aitken's Practice of Medicine, 4th edit, vol. 1. p. 857. See also reports on Hygiene by the writer in the Army Medical Report for 1860, 1861, 1862, and 1863, where references to most of the early cases will be found. See also Dr Thudichum's treatise in Mr Simon's Report to the Privy Council, 1864.

† Levy, "Traité d'Hygiène," t. ii. p. 666; reference to experiments of Danger, Haudin, and Chatin.

heat in a baker's oven and smoking, if it can be used, may lessen the danger. If such things can be got, it would be well to try the effect on the meat of antiseptics, especially of carbolic acid, which destroys low animal life with great certainty.

SUB-SECTION IV.—COOKING OF MEAT.

Boiling.—The loss of weight is about 20 to 30 per cent.; sometimes as much as 40. If it is wished to retain as much as possible of the salts and soluble substances in the meat, the piece should be left large, and should be plunged into boiling water for five minutes to coagulate the albumen. After this the heat can scarcely be too low. The temperature of coagulation of the albuminoid differs in the different constituents, one kind of albumen coagulates at as low a heat as 86° if the muscle serum be very acid; another albumen coagulates at 113° Fahr.; a large quantity of albumen coagulates at 167°, the hæmatoglobulin coagulates at 158° to 162°, below which temperature the meat will be underdone. If the temperature is kept above 170°, the muscular tissue shrinks, and becomes hard and indigestible. Liebig recommends a temperature of 158° to 160°. Most military cooks employ too great a heat: the meat is shrunken and hard. In boiling ammonium, sulphhydrate is evolved, with odoriferous compounds, and an acid like acetic acid.

If it is desired to make good broth, the meat is cut small, and put into cold water, and then warmed to 150°; beef gives the weakest broth. In a pint there are about 140 grains of organic matter, and 90 grains of salts. Mutton broth is a little stronger, and chicken broth strongest of all. About 82 per cent. of the salts of beef pass into the broth, viz., all the chlorides, and most of the phosphates.

Broth made without heat, by the addition of four drops of hydrochloric acid to a pint of water, and a half pound of beef, is richer in soluble albumen. Lactic acid and chloride of potassium added together have the same effect. If rather more hydrochloric acid be used, but no salt, heat can be applied, and, if not higher than 130° Fahr., nearly 50 per cent. of the meat can be obtained in the broth.

Roasting.—The loss varies from 20 to 35 per cent. in beef, it is rather less than in mutton (Oesterlen). This loss is chiefly water; the proportion of carbon, hydrogen, nitrogen, and oxygen remaining the same (Playfair). Roasting should be slowly done; to retain the juices, the meat must be first subjected to an intense heat, and afterwards cooked very slowly; the dry distillation forms aromatic products, which are in part volatilised; the fat is in part melted, and flows out with gelatine and altered extractive matters. The fat often, improperly, becomes the perquisite of the cook, and may be lost to the soldier. The loss in baking is nearly the same, or a little less.

Stewing.—This is virtually the same as roasting, only the meat is cut up, is continually moistened with its own juices, and is often mixed with vegetables. Like boiling and roasting, it should be done slowly at a low heat; the loss is then about 20 per cent., and chiefly water.

In all cases, there is one grand rule, viz., to cook the meat slowly, and with little heat, and, as far as possible, to let the loss be water only. The fault in military kitchens has been, that excessive heat is used. I have frequently seen the water boiling, and the men have told me that, in order to boil the vegetables, and yet not overdo the meat, they are obliged to remove the meat for a time from the water. The meat is then often a sodden, tasteless mass, with hard, shrunken, and indigestible fibres. Happily, one of the improvements introduced by Lord Herbert was regular instruction of soldiers in cooking, and this is now being carefully done. But medical officers should interest

themselves in this subject, which is of such importance for health. The thermometer will be found very useful, especially in showing cooks that the temperature is often much higher than they think.

In cutting up meat, there is a loss of about 5 per cent., and there is also a loss from bone, so that, all deductions being made, the soldier does not get more than 5 or 6 ounces of cooked meat out of 12 ounces. In the cooking of salt meat, the heat should be very slowly applied, and long continued; it is said that the addition of a little vinegar softens the hard sarcolemma, and it is certain that vinegar is an agreeable condiment to take with salt meat, and is probably very useful. It may be of importance to remember this in time of war.

It has lately been shown, that the large quantity of flesh-extract contained in the brine can be obtained by dialysis. Place the filtered brine in a bladder or vessel of the prepared dialysis-parchment, and place it in a large vessel with water; the salt diffuses out, leaving, in three or four days, the extract behind; from two gallons of brine a fluid was obtained, which, on evaporation, yielded 1 ℔ of extract (Whitelaw, *Chemical News*, March 1864). The liquid left in the dialyser may be mixed with flour, and then forms a nutritious meat-biscuit (Whitelaw). Instead of pure water in the outer vessel, salt water may be at first used. An air-bladder will do as a dialyser if the parchment cannot be obtained. Mr Whitelaw (*Chemical News*, May 1864) has also suggested a process for converting salt meat into fresh. Place the meat and some brine in a dialyser (made of untanned skin, or any material which can be obtained), and insert in sea-water. The salt of the brine passes into the sea-water; the salt of the meat into the brine; and the meat takes up from the brine some of the natural juice which has previously passed into the brine. It swells, and becomes, in reality, fresh meat. If bags could be procured, this process would be very useful at sea.

SUB-SECTION V.—PRESERVATION OF MEAT.

Meat may be kept for some time by simply heating the outside very strongly, so as to coagulate the albumen; or by placing it in a close vessel, in which sulphur is burnt, or by covering the surface with charcoal, or strong acetic acid, or calcium bisulphite, or weak carbolic acid. Injections of alum and aluminium chloride through the vessels will preserve it for a long time; water should be injected first, and then the solution. Even common salt injected in the same way will keep it for some time. So also will free exposure to pure air; charcoal thrown over it, and suspended also in the air; or the meat being cut into smaller portions, and placed in a large vessel, heat should be applied, and, while hot, the mouth of the vessel should be closed tightly, with well washed and dried cotton-wool; the air is filtered, and partially freed from germs. The application of sugar to the surface is also a good plan.

Plans of this kind may be useful to medical officers under two circumstances, viz., on board ship, and in sieges, when it is of importance to preserve every portion of food as long as possible. The covering the whole surface with powdered charcoal is perhaps as convenient as any plan. A coating of paraffine, and many other plans of excluding air, are also used.

Meat is also preserved in tin cases, either simply by the complete exclusion of air (Appert's process), or by partly excluding air, and destroying the oxygen of the remaining part by sulphite of soda (M'Call's process). It is not necessary to raise the heat so high in this case, and the meat is less sapid. Meat prepared in either way has, it is said, given rise to diarrhœa, but this is

simply from bad preparation; when well manufactured it has not this effect. (See also chapter on CONCENTRATED FOOD.)

Meat is also preserved by drawing off the air from the case and substituting nitrogen and a little sulphurous acid (Jones and Trevithick's patent), or the air can be heated to 400° or 500°, so as to kill all germs (Pasteur), and then allowed to flow into an exhausted flask.*

SECTION II.

WHEAT.

Advantages as an Article of Diet.—It is poor in water and rich in solids, therefore very nutritious in small bulk; when the two outer coats are separated, the whole grain is digestible. The nitrogenous substances are large and varied, consisting of soluble albumen (1 to 2 per cent.), and gluten (8 to 12 per cent.), which itself consists of three or four substances (mucin or vegetable casein, glutin, or gliadin or vegetable gelatin, which gives the adhesiveness and power of rising in fermentation, and vegetable fibrin).† The starchy substances (starch, dextrin, sugar) are large, 60 to 70 per cent., and are easily digested; and, according to Mége-Mouriès, a nitrogenous substance (cerealin) is contained in the internal envelope, which, like diastase, acts energetically in transforming starch into dextrin, sugar, and lactic acid. Some consider this cerealin to be merely a form of diastase. The salts (see table, p. 167) are chiefly phosphates of potash and magnesia.

Disadvantages.—It is deficient in fat, and in vegetable salts which may form carbonates in the system.

As usually prepared, the grain is separated into flour and bran; the mean being 80 parts of flour, 16 of bran, and 4 of loss. The flour is itself divided into best or superfine, seconds or middlings, pollards or thirds or bran flour. In different districts different names are used. The wheats of commerce are named from colour or consistence (hard or soft); the hard wheat contains less water, less starch, and more gluten than the soft wheat.

SUB-SECTION I.—WHEAT GRAINS.

The medical officer will seldom be called on to examine wheat grains, but if so, the following points should be attended to. The grains should be well

* Those who wish to see a good account of the different patents for the preservation of meat and other foods, should refer to Dr Letheby's Cantor Lectures on Food, delivered before the Society of Arts in 1860, *Chemical News*, Dec. 11, 1868.

† These are the substances found by Ritthausen and Von Bibra. Günsberg has given rather different results ("Watt's Dict. of Chemistry," article *Gluten*, vol. ii. p. 875). The following table is taken from Von Bibra:—

Composition of Gluten from the finest Meal in 100 *parts of Gluten* (*after Von Bibra.*)

	1.	2.	3.	4.
Vegetable fibrin, . .	70·95	71·55	69·40	70·48
Vegetable glutin, . .	14·40	16·00	17·57	16·92
Vegetable casein, . .	8·80	6·53	7·30	6·33
Fat, ...	5·85	5·92	5·73	6·27

In poor wheat the vegetable fibrin is larger, the gluten and casein are in much less amount, sometimes scarcely ½.

The fibrin contains		1·2	per cent. of	S. and
		0·3	,,	P.
The glutin	,,	0·88	,,	S.
The casein	,,	0·68	,,	S.

filled out, of not too dark a colour; the furrow should not be too deep; there should be no smell, no discoloration, and no evidence of insects or fungi. The heavier the weight the better. In the Belgian army the minimum weight is 77 kilogrammes the hectolitre.* In England, good wheat weighs 60 ℔ to the bushel; light wheat 58 ℔, or even 50 ℔. The fungi, if present, will be found at the roots of the hairs, and if in small amount, are only microscopic. If in large amount they cause the diseases known by the name of rust, bunt or smut, or dust brand; they are owing to species of Uredo and Puccinia. (See FLOUR.†) If any grains are seen pierced with a hole, and on examination are found to be a mere shell, with all the starch gone, this is owing to the weevil, and the little insect can itself be found readily enough if a handful of wheat be taken and spread over a large plate. The weevil can hardly escape being seen. (See fig. 37, p. 206.) The *Acarus farinæ* (see FLOUR) may also prey on the wheat grain, but cannot be seen without a microscope.

SUB-SECTION II.—FLOUR.‡

Almost all the bran is separated from the finest flour; it has been a question whether this is desirable, as the bran contains nitrogenous matter—as much sometimes as 15 per cent., with 3·5 per cent. of fat, and 5·7 per cent. of salts. But if the bran is used, it seems probable that much is left undigested, and all the nutriment which is contained in it is not extracted (Poggiale). A plan has been lately employed by Mége-Mouriès, which seems to save all the most valuable parts of the bran; the two or three outer and highly siliceous envelopes of the wheat are detached, and the fourth or internal envelopes are left. Several plans of decorticating wheat have been proposed, and some of them seem likely to supersede the old system of grinding.

By a special manipulation and fermentation, Mouriès proposes to so far alter the cerealin that its energetic action on starch and production of acid is lessened, while all the really nutritious parts of the envelopes are preserved.§ If the whole bran is used, it should be ground very fine, as the harder envelopes are very irritating, and it is well to remember that for sick persons with any bowel complaints bread must be used entirely without bran. I have found dysenteries most intractable, merely from attention not being directed to this simple point.

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* Squillier, Des Subsist. Mil. p. 37.

† The brand of wheat and other cereals is owing to the Uredo or Puccinia, the species being *sitophilum* or *segetum*. Rye, maize, millet, &c., appear to have their own species.

‡ The following, after Peligot (mean of 14 analyses), may be taken as the mean composition of flour. The analyses of Von Bibra (Die Getreidearten und das Brod, 1860) agree very closely with it:—

Wheat Flour and Bran.	In 100 parts. Flour.	Bran.
Water,	14	10·3
Fatty matters,	1·2	2·82
Nitrogenous substances insoluble in water (gluten),	12·8	10·84
Nitrogenous substances soluble in water (albumen),	1·8	1·64
Non-nitrogenous soluble substances (dextrin, sugar),	7·2	5·8
Starch,	59·7	22·62
Cellulose,*	1·7	43·98
Salts,	1·6	2·52

§ See his papers in the "Comptes Rendus de l'Acad." vols. 37, 38, 42, and Chevallier's Report, Jan. 1857.

* This is, however, the cellulose of the entire grain, both of the husk and the interior of the grain. The salts are given at page 167; the potash, phosphoric acid, and magnesia are the principal ingredients; the earthy phosphates are especially combined, and in definite proportions, with the albuminates (Mayer), and also the gummy matter (Bibra). The alkaline phosphates free. The bran contains much silica. Oudemans places the cellulose lower (25 to 30 per cent.), and the salts higher (4 to 6 per cent.).

Examination of Flour for Quality and Adulteration.

Flour should be examined physically, microscopically, chemically, and practically by making bread.

The quality is best determined by chemical examination; adulterations by the microscope.

Physical Examination.

Sight.—The starch should be quite white, or with the very slightest tinge of yellow; any decided yellow indicates commencing changes; the amount of bran should not be great.

Touch.—There should be no lumps, or, if there are, they should at once break down on slight pressure; there must be no grittiness, which shows that the starch grains are changing, and adhering too strongly to each other, and will give an acid bread. There should, however, be a certain amount of adhesion when a handful of flour is compressed, and if thrown against a wall or board some of the flour should adhere. When made into a paste with water, the dough must be coherent, and draw out easily into strings.

Taste.—The taste must not be acid, though the best flour is slightly acid to test-paper. An acid taste, showing lactic or acetic acids, is sure to give an acid bread.

Smell.—There must be no smell of fermentation or mouldiness.

Age of flour is shown by colour, grittiness, and acidity.

Chemical Examination.

It is seldom that a medical officer will be able to go through a complete examination, but he should always determine the following points:—

1. *Amount of Water.*—Weigh 1 gramme, spread it out on a dish, and dry either by a water bath or in a hot-air bath or oven, the temperature not being allowed to go above 200°. The flour must not be at all burnt or much darkened in colour. Weigh directly the flour is cold; the loss is the percentage of water.

The range of water is from 10 (in the best dried flours) to 18 in the worst. The more water the greater liability of change in the flour, and, of course, the less is the amount of nutriment purchased in a given weight. If, then, the water be over 18 per cent., the flour should be rejected; if over 16, it should be unfavourably spoken of.

2. *Amount of Gluten.*—Weigh 10 grammes (or 100 grains, if there are no gramme weights), and mix, by means of a glass rod, with a little water, so as to make a well-mixed dough; let it stand for half-an-hour in an evaporating dish; then pour a little water on it; work it about with the rod, and carefully wash off the starch; pour off from time to time the starch water into another vessel. After a time, the gluten becomes so coherent, that it may be taken in the fingers and worked about in water, the water being from time to time poured off till it comes off quite colourless. If there is not time to dry the gluten, then weigh; the dry gluten is rather less than one-third the weight of the moist; 1 to 2·9 is the usual proportion; therefore divide the weight of the moist gluten by 2·9. If there be time, dry the gluten thoroughly, and weigh it. The dry gluten ranges from 8 to 12 per cent.; flour should be rejected in which it falls below 8. If there is much bran, it often apparently increases the amount of gluten by adhering to it, and should be separated if possible. The gluten should be able to be drawn out into long threads; the more extensible it is the better. It is always well to make two determinations of gluten, especially if there is any disputed question of quality. When the

wet gluten is exposed to a temperature of 410° Fahr. in an oil bath, it swells to from 2 to 6 times its volume, and this has been used as a test of goodness; the greater the swelling, the better the flour.*

3. *Amount of Ash.*—Take 10 grammes, put into a porcelain or platinum crucible, and incinerate to white ash. Weigh. The ash should not be more than 2 per cent., or probably some mineral substances have been added; it should not be less than ·8, or the flour is too poor in salts.

It will not be easy for the medical officer to incinerate the flour, as it requires a crucible and gas. It is difficult to do it over a spirit lamp, as it takes a long time. A small charcoal fire is probably the best plan when appliances are wanting.

If the ash be more than 2 per cent., add hydrochloric acid, and see if there be effervescence (magnesium or calcium carbonate). Dissolve, and test with oxalate of ammonia, and then for magnesia, in the same way as in water. As flour contains both lime and magnesia, to prove adulteration, the precise amount of lime and magnesia must be determined by weighing the incinerated calcium oxalate, or the magnesium pyrophosphate.

If there is no effervescence, add water, and test for sulphuric acid and lime, to see if calcium sulphate (plaster of Paris) has been added. In normal flour the amount of sulphuric acid is very small.

Notice, also, if the ash be red (from iron). If clay has been added, it will be left undissolved by acids and water.

If magnesium carbonate has been added, the ash is light, and porous and bulky (Hassall).

An easy mode of detecting large quantities of added mineral substances is given by Redtenbacher; the flour is strongly shaken with chloroform; the flour floats, while all foreign mineral substances fall. This is a very useful test.

4. The remaining ingredients can be determined, if necessary, from the starch water, but it is seldom necessary to do so. Allow the starch to subside, pour off the fluid, and wash the starch by decantation, then dry and weigh; take all the water and washings, evaporate to a small bulk, add a little nitric acid, and boil; albumen is thrown down; collect, wash, and weigh. Evaporate the whole of the remainder to dryness, and weigh (mixed dextrin and sugar).

If the water be small, the gluten large, and the salts in good quantity, the flour is good, supposing nothing is detected on microscopical examination. But in all cases it is well, if time can be spared, to have a loaf made.

Practical Test by Baking.—Make a loaf, and see if it is acid when fresh, and how soon it becomes so; if the colour is good, and the rising satisfactory. Old and changing flour does not rise well, gives a yellowish colour to the bread, and speedily becomes acid. Excess of acidity can be detected by holding a piece of bread in the mouth for some time, as well as by test-paper.

Test for Ergot.—There is no very good test for ergot when it is ground up with the flour. Laneau's plan is to make a paste with a weak alkaline solution; to add dilute nitric acid to slight excess, and then alkali to neutralisation; a violet-red colour is said to be given if ergot is present, which becomes rosy-red when more nitric acid is added, and violet when alkali is added.

Wittstein considers this method imperfect, and prefers trusting to the peculiar odour of propylamine (herring-like smell), developed by liquor potassæ in ergoted flour. I have no experience of this point.

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* Payen, Des Subst. Alim., 4th ed. 1865, p. 278.

Microscopical Examination.

This is especially directed to determine the relative amount of flour and bran, the presence of fungi or acari, or the fact of adulteration by other grains.

Structure of the Wheat Grain.—It is necessary to refer briefly to the structure of the grain of wheat, as this, of course, must be thoroughly understood.

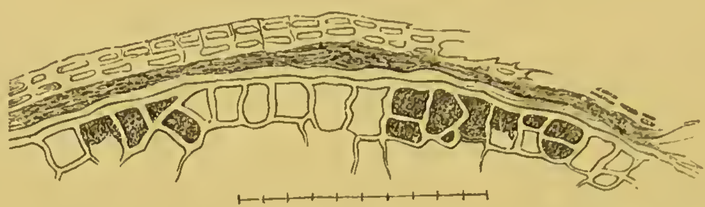


Fig. 27.—Transverse Section of Envelopes of Wheat. Scale 1000th of an inch.

There are four envelopes (some authors make three, others five or six—the outer coat being divided into two or three), surrounding a fine and very loose areolar tissue of cellulose filled with starch grains.

Envelopes of Wheat.—The drawings show the coats *in situ*, cut transversely

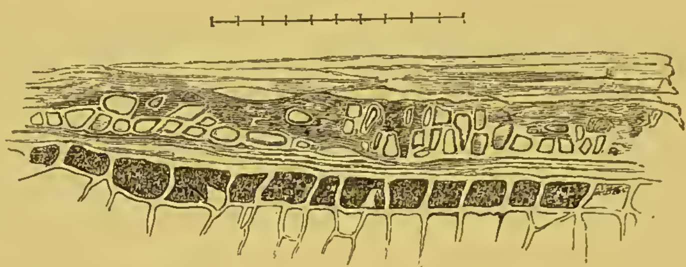


Fig. 28.—Envelopes of Wheat (longitudinal section). Scale 1000th of an inch.

and longitudinally, also the separate coats. The outer coat is made up of two or three layers of long cells, with slightly beaded walls, running in the direction of the axis of the grain. The septa are straight or oblique, and, as will

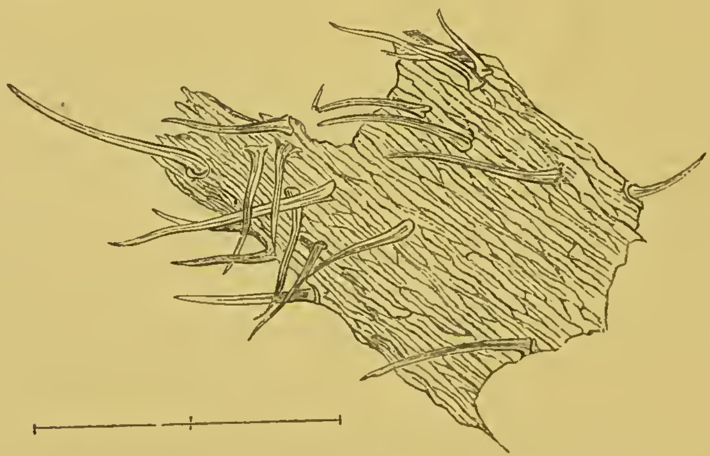


Fig. 29.—Outer Coat and Hairs of Wheat. Scale 100th of an inch.

be seen, the cells differ in length and breadth. The size can be taken by the scale. The hairs are attached to this coat, and are prolongations, in fact, of

the cells. In the finest flour the hairs and bits of this coat (as well of the other coats) can be found.

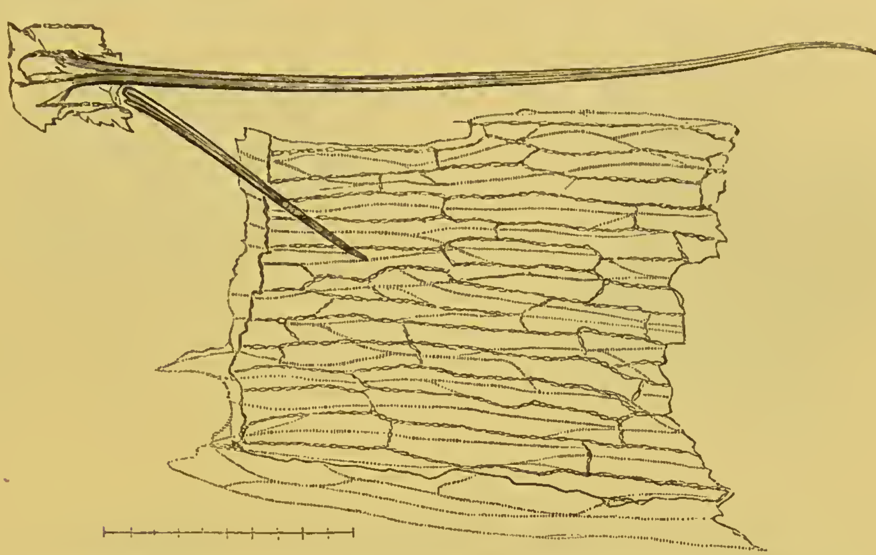


Fig. 30.—Outer Coat and Hairs of Wheat. Scale 1000th of an inch.

The second coat, counting from without, is composed of a layer of shorter cells, more regular in size, with slightly rounded ends, and lying at right angles to the first coat, or across the axis of the grain. It is impossible to mistake it. The third coat is a delicate diaphanous, almost hyaline mem-

Fig. 31.—Second and Third Envelopes of Wheat. Scale 1000th of an inch.

brane, so fine that its existence has been doubted. Dr Maddox, however, has distinctly shown it to have faint lines on it, as seen in the drawing, which may be cells. In the transverse section of the envelope it appears as a thin white line. Internal, again, to this coat what appears to be another coat can sometimes be made out; it is a very fine membrane, marked with widely

separated lines, which look like the outlines of large round or oval cells. The

Fig 32.—Fourth Envelope of Wheat. Scale 1000th of an inch.

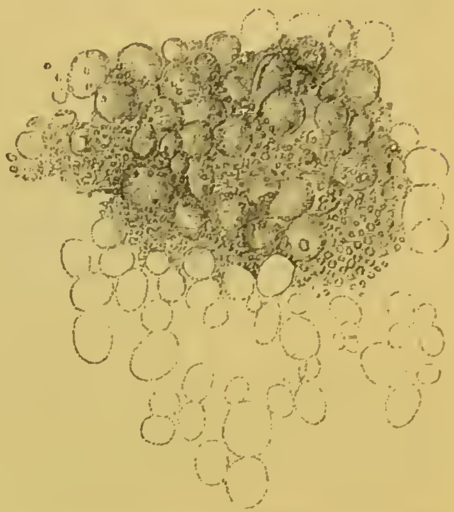


Fig. 33.—Fresh Starch-grains of Wheat (moistened) × 360.

internal or fourth coat, as it is usually called, is composed of one or two layers

Fig. 34.—Dried and then moistened Starch-grains of Wheat. Scale 1000th of an inch.

(in places) of rounded or squarish cells filled with a dark substance which can

Fig. 35.—Diseased Flour (Puccinia).

be emptied from the cells. When the cells are empty, they have a remote

resemblance to the areolar tissue of the leguminosæ, and there is little doubt that from this cause adulteration with pea or bean has been sometimes improperly asserted.

The Starch Grains of wheat are very variable in size, the smallest being almost mere points, the largest $\frac{2}{1000}$ths of an inch in diameter or larger. In shape the smallest are round; the largest round, oval, or lenticular. It has been well noticed by Hassall that there is often a singular want of intermediate-sized grains. The hilum, when it can be seen, is central, the concentric lines are perceived with difficulty, and only in a small number; the edge of the grain is sometimes turned over so as to cause the appearance of a slight furrow or line along the grain. Very weak liquor potassæ causes little swelling; strong liquor potassæ bulges them out, and eventually destroys them. There is no difficulty in seeing if the pieces of envelopes are too numerous, but it should be remembered the best flour contains some.

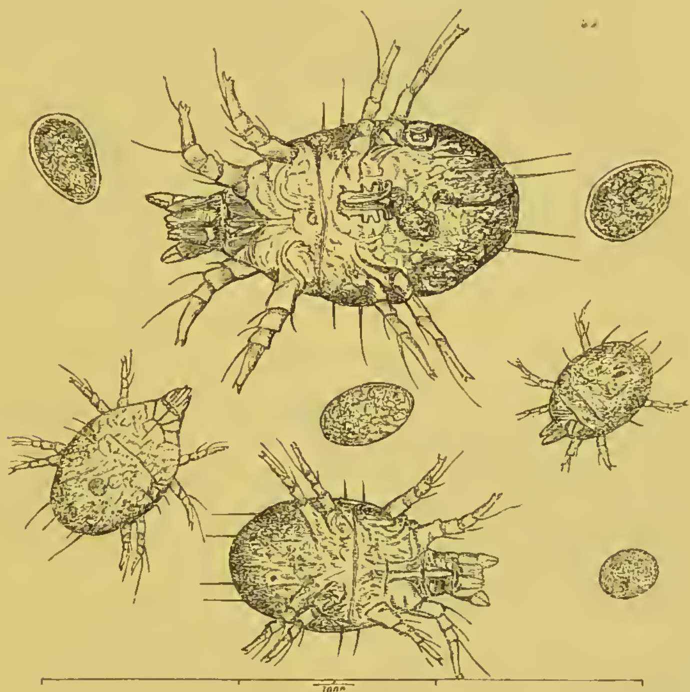


Fig. 36.—*Acarus farinæ* (×85 diameters).—Mites found in flour alive. In the largest figures, the insects are considerably compressed, to show the powerful mandibles, and have each a ventral aspect. In the smallest and middle-sized insect, we have drawn the dorsal aspect; the former only possesses six legs, as before the first moult; several ova lie scattered in the field of view. It is unknown what office the capsular organs fulfil. They are well seen on each side of the largest figure.

Diseases of Flour.—Some substances are found in flour, viz., fungi and animals.

Fungi.—Several fungi are found in wheat-flour. The most common fungus is a species of Puccinia. It is easily recognised by its round dark sporangia, which are either contoured with a double line, or are covered with little projections. It is said not to be injurious by some, but this is very doubtful. The symptoms have not been well described.

The smut, or caries, is also a species of Puccinia; has large sporules, and gives a disagreeable smell to the flour, and a bluish colour to the bread. It is said to produce diarrhœa.

Acarus.—The *Acarus farinæ* is by no means uncommon in inferior flour,

especially if it is damp. It does not necessarily indicate that leguminous seeds are present, as stated. It is no doubt introduced from the grain in the mill, as I have found it adhering to the grain itself. It is at once recognised. Portions of the skin are also sometimes found.

Vibriones.—These form for the most part in flour which has gone to extreme decomposition, and which is moist and becoming discoloured. They cannot be mistaken.

The presence of Acari always shows that the flour is beginning to change. A single acarus may occasionally be found in good flour, but even one should be looked on with suspicion, and the flour should be afterwards frequently examined to see if they are increasing.

Fig. 37.
Weevil—Natural size.

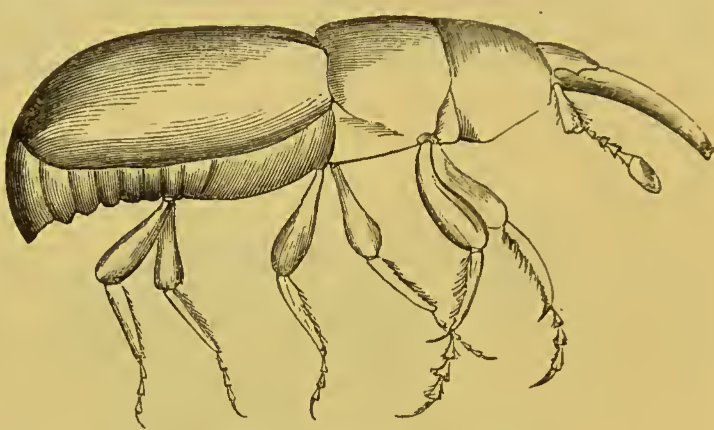


Fig. 38.—Weevil. Magnified 12 diameters.

Weevil (Calandra granaria).—The weevil is of course at once detected. It is by no means so common in flour as in corn.

Adulterations of Wheat-Flour.—At present there is very little adulteration of wheat-flour in this country, but should the price rise again, the case will be different. Abroad, adulteration is probably more common, and the medical officer must be prepared to investigate the point.

The chief adulterations are by the flour of other grains, viz.:—

Barley,	Rice,	in some countries,
Potato,	Buckwheat,	
Beans and peas,	Millet,	
Maize,	Linseed,	
Oat,	Melampyrum,	
Rye,	Lolium,	

and other grains noticed farther on. All these are best detected by the microscope.

Fig. 39.—Barley—Longitudinal Section. Scale is the same as that of the Starch-grains.

Other adulterations are by mineral substances, viz.:—

Alum,	Powdered flint,
Gypsum,	Calcium and magnesium carbonate.
Clay,	

These are best detected by chemical examination. (For the detection of alum, see the chapter on Bread.)

Detection of Barley.—This is not easy, but can, with care, be often done.

The envelopes of barley are the same in number as those of wheat, but they are more delicate. The outer coat has three layers of cells; the walls of the

Fig. 40.
Outer Coat and Hairs of Barley (low power).

Fig. 41.
Outer Coat of Barley (higher power).

external layer are beautifully waved, but not beaded; the cells are smaller than those of the outer coat of wheat. The second coat, disposed at right

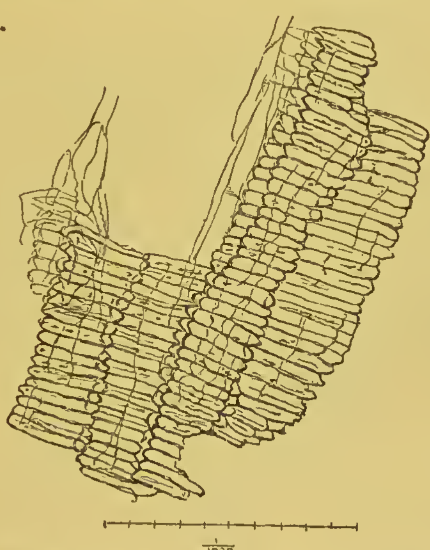


Fig. 42.—Barley (second and third coats).

angles to the first, as in wheat, is like the second coat of wheat, except in being more delicate. The third is hyaline and transparent, as in wheat.

The fourth has the cells similar in shape to the corresponding wheat coat, but they are very much smaller, as may be seen on reference to the scale, and there are two, or often three, layers.

The *starch grains* of barley are very like the wheat, with a central hilum and obscure marking, but are on the whole smaller; some have thickened edges, instead of the thin edges of the wheat-starch grain, but it is very

1/1000

Fig. 43.—Barley (fourth coat).

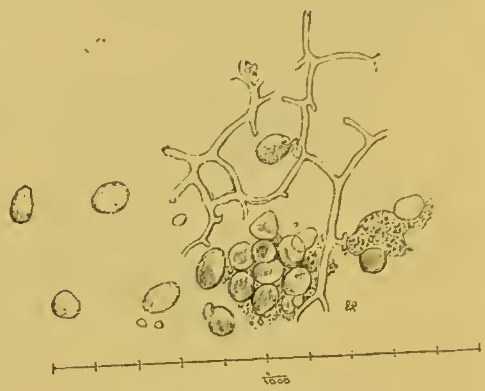


Fig. 44.—Barley (Starch-grains).

difficult, and sometimes impossible to distinguish them. It is therefore especially to the envelopes that we must attend.

Detection of Potato Starch.—This is a matter of no difficulty; the starch grains, instead of being round or oval, and with a central hilum and obscure rings, are pyriform, with an eccentric hilum placed at the smaller end, and with well-marked concentric rings. Weak liquor potassæ (1 drop of pharmacopœial liq. pot. to 10 of water) swells them out greatly after a time, while

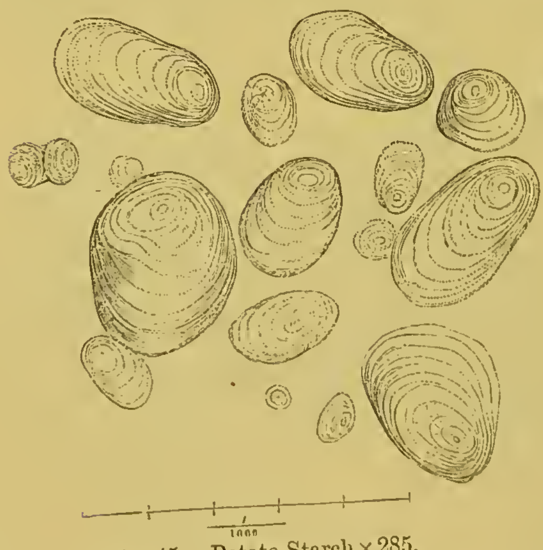
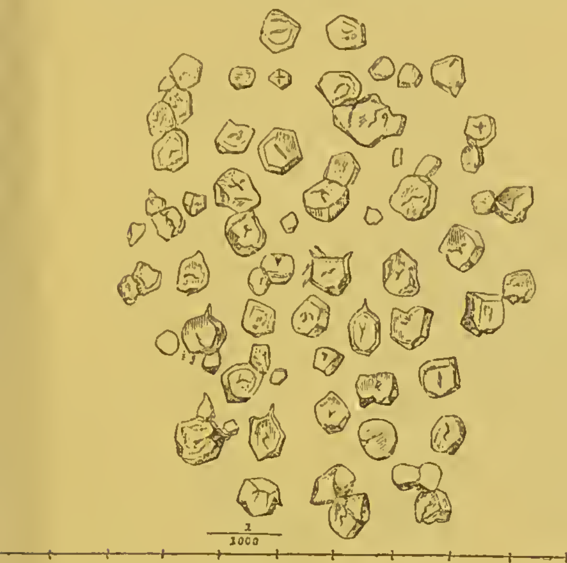


Fig. 45.—Potato Starch × 285. See also Plate of Starches.

Fig. 46.—Medium and small-sized Potato starch-grains, treated with Liq. Pot. Ph. Lond. One-third part and water × 285.

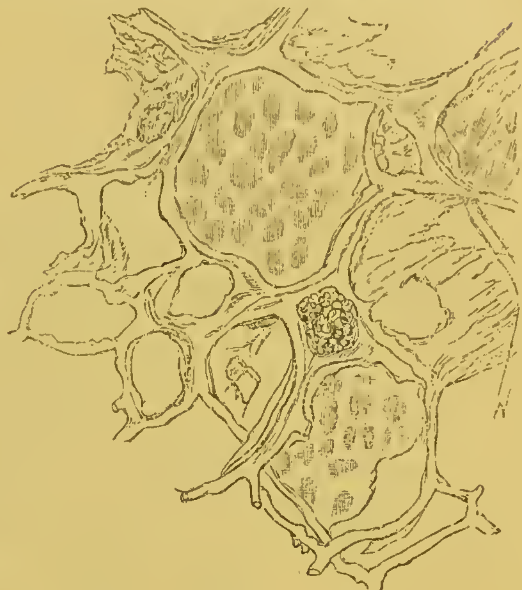
wheat-starch is little affected by this strength; if the strength is 1 to 3 (as in the figure), the swelling is very rapid.

Detection of Maize (Indian Corn).—There are two envelopes; the outer being made up of seven or eight strata of cells; there is no transverse second



×250

Fig. 47.—Indian-Corn Flour. See also Plate of Starches.



Cellulose of Indian Corn × 500, with markings from the starch-grains on the intercellular membrane.

coat, as in wheat; the internal coat consists of a single stratum of cells like the fourth of wheat, but less regular in shape and size. The cellulose, through the seed holding the starch in its meshes, forms a very characteristic structure, which on section looks like a pavement made of triangular or square pieces; the cells are filled with the starch-grains, which are very small, and compressed, so as to have facets. They are very different from the smooth, uncompressed round cells of wheat.

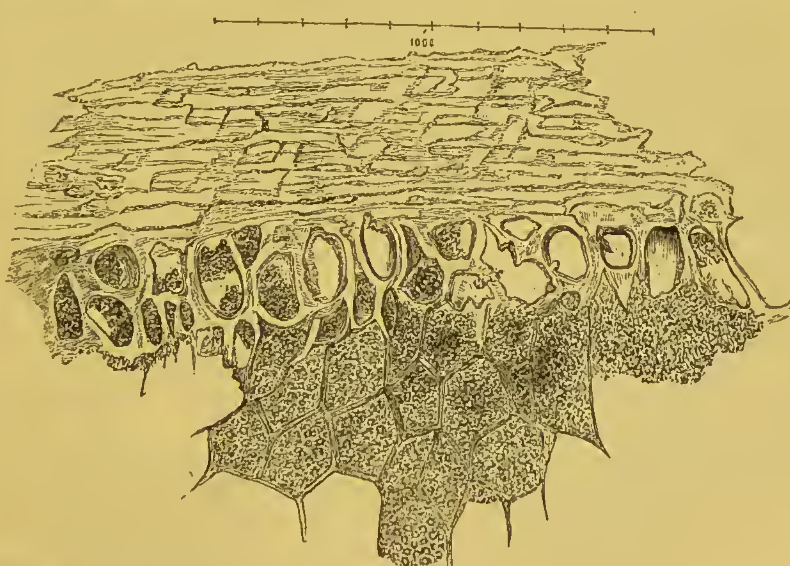


Fig. 48.—Longitudinal section of Coats of Indian Corn and Cellulose × 190.

Bits of cellulose, with its peculiar angular markings, are always found if the wheat is adulterated with maize.

Detection of Bean and Pea.—These adulterations are also at once discovered; the meshes of cellulose are very much larger than those of the fourth coat of wheat, with which it has sometimes been confounded, and the starch-grains are also quite different; they are oval or reniform, or with one end slightly larger; they have no clear hilum or rings, but many have a deep central longitudinal cleft running in the longer axis, and occupying two-thirds

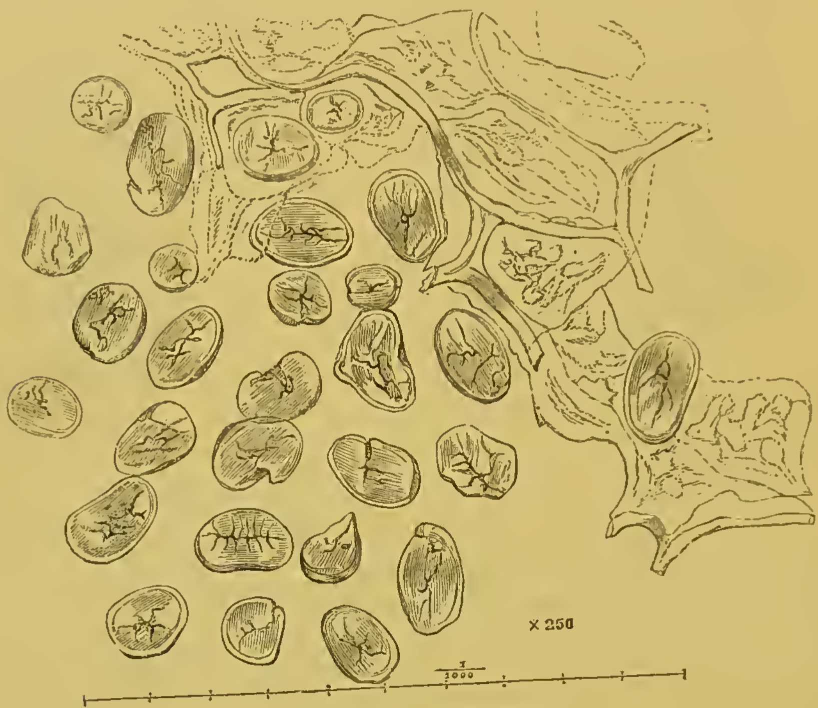


Fig. 49.—Bean Starch.

or three-fourths of the length, but never reaching completely to the end; this cleft is sometimes a line, sometimes almost a chasm, and occasionally secondary clefts abut upon it at parts of its course; sometimes, instead of a cleft, there is an irregular-shaped depression. If a little liquor potassæ be added, the cellulose is seen more clearly. Pea flour is never added to a greater extent than 4 per cent., as it makes the bread heavy and dark. If the flour be mixed with a little boiling water, the smell of the pea or bean is perceptible.

A chemical test has been given by Donné to detect admixture of garden beans. The powder is smeared round the inside of a small vessel; at the bottom of the vessel seven or eight drops of nitric acid are allowed to fall, and are evaporated by aid of a lamp, the vessel being partly covered to prevent too rapid evaporation; when the flour has partly become brown, a few drops of ammonia are put in the capsule, and left to spontaneous evaporation. A beautiful red colour forms about the centre of the flour where the action of the nitric acid has been neither too

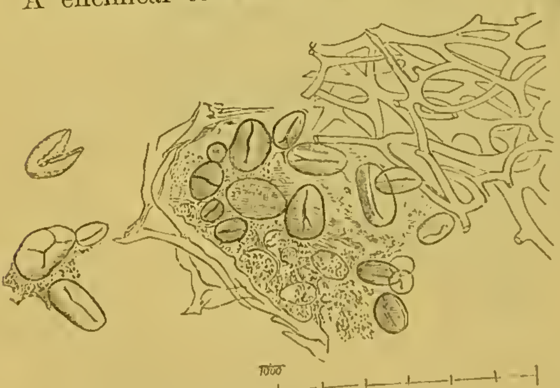


Fig. 50.—Pea Flour.

strong nor too feeble. A lens will pick out at once the red points of the

Fig. 51.—White Oat—Long. sect., 2d and 3d coats not separable. *a* Compound grains × 100; *b* One do. × 500.

bean flour. This reaction must be marked to be of any value.* Several other tests have been given, but are imperfect and really unnecessary, for the microscopic characters are sufficient.

Detection of Oat.—There are two or three envelopes; the outer longitudinal cells; the second obliquely transverse, and not very clearly seen; the cells are wanting in parts, or pass into the cells of the third coat; the third a layer, usually single, of cells like wheat. The starch-cells are small, many-sided, and cohere into composite round bodies, which are very characteristic, and which can be broken down into the separate grains by pressure. A high power is the best for this. The oat starch does not polarise light. There is no difficulty in the detection of the starch grains.

Fig. 52 -Ground Rice Flour × 350.

Detection of Rice.—The husk of rice is very peculiar; on the outer coat

* Stas has given facts which appear to greatly lessen its value.—Squiller, *Des Subsist. Mil.* p. 93.

are numerous siliceous granules, arranged in longitudinal and transverse

Fig. 53.—Rice × 170.

Fig. 54.—Rice × 170.

Fig. 53. Transverse section of the Husk of Rice, ... } × 170.
Fig. 54. Appearance of Husk as seen in a transparent medium of glycerine and gum, }
a Siliceous granules, arranged in longitudinal and transverse ridges, perforated by openings—stomata, some having hairs seated over them. *b c* Transverse and longitudinal, brittle, rough-edged fibres. *d* A fine membrane of transverse angular cells; these overlie a very delicate membrane of large cells *e*.

ridges (*a*). There are numerous hairs, some of which are seated over stomata. Below this is a membrane of transverse and longitudinal rough-edged fibres (*b c*), while below these again is a fine membrane of transverse angular cells (*d*), covering a very delicate membrane of large cells. The starch corpuscles are very small; angular under low powers; under high powers they are seen to be facetted and compressed. They cannot be mistaken for the round cells of wheat, but may be confounded with maize. As will be seen on reference to the scale, they are, however, much smaller.

Fig. 55.—Rye-starch, with rayed hilum (after Hassall) × 420.

Detection of Rye.—The envelopes are very like those of wheat, and can perhaps be hardly distinguished. The recent starch-grains are also extremely like those of wheat, but the older and drier grains have sometimes a peculiar rayed hilum. I have seen this, however, in very old wheat, but never to the same extent as in rye.

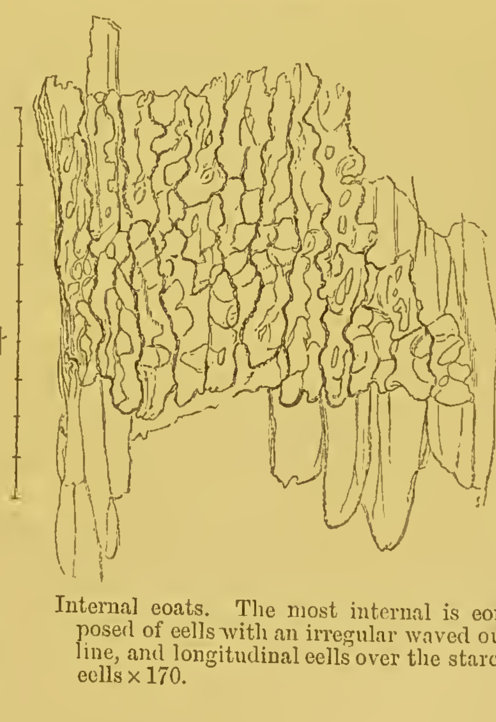
Rye, if in any quantity, is discovered by baking; it makes a dark, acid bread.

Linseed is not a common adulterant. The envelopes are peculiar: the external is made up of hexagonal cells, containing

oil; the second of round cells; the third of fibres; and the fourth of angular cells, containing a dark reddish colouring matter.

Fig. 56.—Rye—1. Transverse section of Testa, &c. × 108; 2. Coats *in situ* from without, × 170. *a* External; *b* Middle; *c* Internal coat; *d* Starch-grains × 108.

Fig. 57.—Outer coat of Buckwheat, apparently of irregular and interlacing fibrospiral cells, separable by boiling the testa and macerating it. Outside these cells is a very thin and delicate membrane, retaining the marks of attachment of the spiral cells × 170.



Internal coats. The most internal is composed of cells with an irregular waved outline, and longitudinal cells over the starch-cells × 170.

Buckwheat (Polygonum Fagopyrum, or Fagopyrum esculentum).—Like

rye, this is only likely to be found in wheat coming from the Baltic. The drawing sufficiently shows the texture of the envelopes, which is very com-

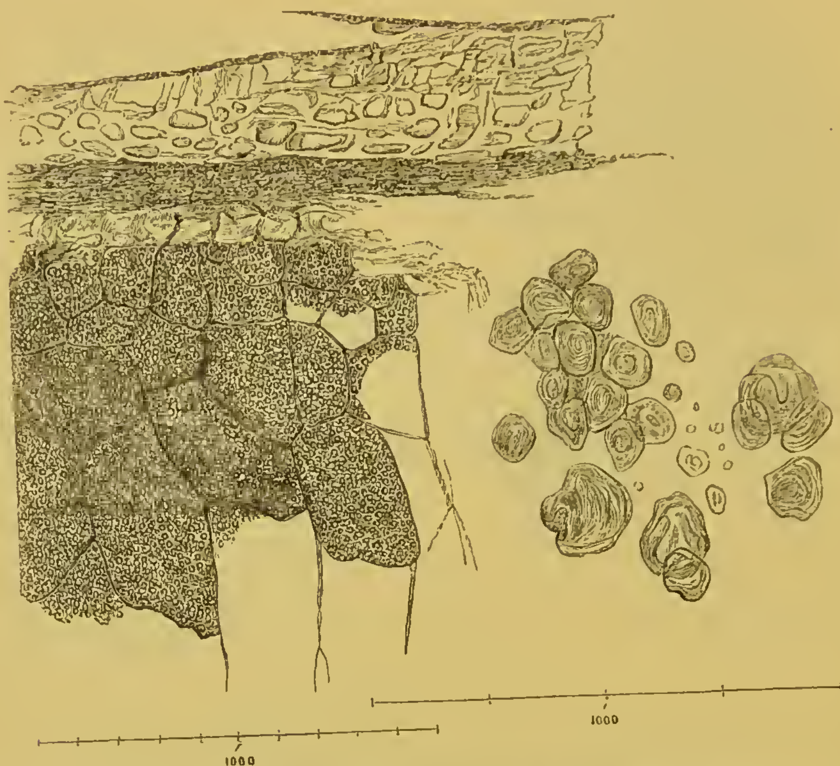


Fig. 58.—Buckwheat—Transverse section of outer, middle, and internal coats, with cellulose containing starch-grains, . . } × 170. Starch-grains × 500.

plicated. The starch-grains are small and round, and adhere together in masses. Under a high power there are indications of concentric rings. Bread made with this grain has a darkish, somewhat violet, colour.

Millet.—In India, Egypt, China, and West Coast of Africa, millet of some kind is likely to be an adulteration. Dr Maddox's drawing shows the beautiful structure of the envelopes, which could not be confounded with those of wheat. The starch-grains are very small, round, and tolerably uniform in size.

Melampyrum arvense and other species (Purple Cow-wheat—*Scrophulariaceæ*).—This has occasionally been mixed with flour; it is not injurious, but gives the bread (not the flour) a peculiar smoky violet or bluish-violet tint. This depends on a colouring matter in the seed, which, when warmed with acid, gives the violet colour.*

Trifolium arvense (Trefoil—*Leguminosæ*).—This also gives the bread a red violet colour. It is not known to be injurious.

Rhinanthus major and *minor* (Sainfoin or Yellow rattle—*Scrophulariaceæ*) gives bread a bluish-black colour, a moist sticky feel, and a disagreeable sweet taste. It is not injurious.

Lolium temulentum (Rye-grass—*Gramineæ*. Other species may be used). —This gives the bread no colour, but produces narcotic symptoms, vertigo,

* Pellischek, Schmidt's Jahrb. 1863, No. 3, p. 287.

hallucinations, delirium, convulsions, and paralysis.* Pellischek states that these symptoms do not occur if the grain be dried in an oven before baking,

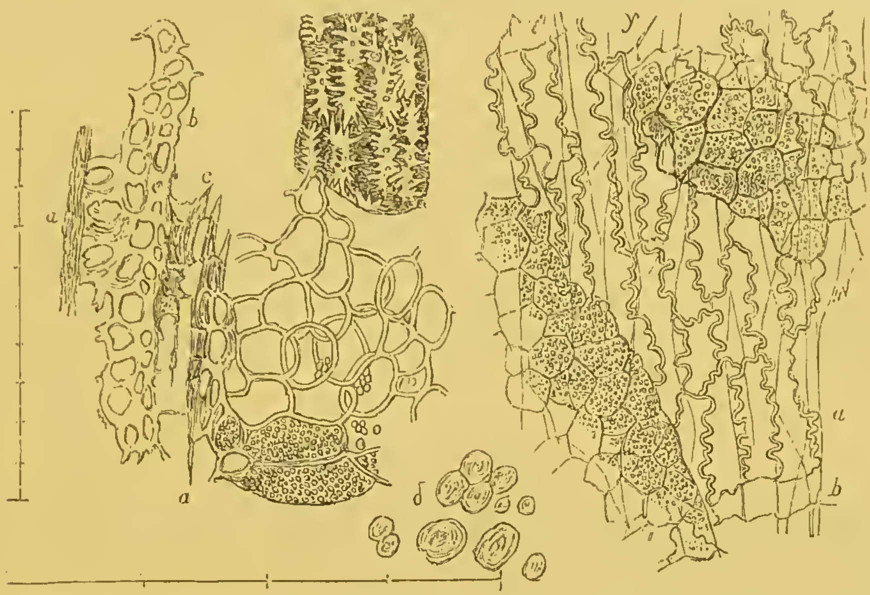


Fig. 59.—Millet Seed—*a* Transverse section of Testa coats, seen from inside; *a* Outer; *b* Middle; *c* Inner coat × 170; δ Starch-grains × 500. Scale 1-1000th inch.

or if the bread is left for some days before being used. The detection of the lolium is best effected by means of alcohol, which gives a greenish solution with a disagreeable repulsive taste, and on evaporation a resinous yellow-

* The peculiar symptoms produced by the *Lolium temulentum* or bearded Darnel, were well known to the ancients. Pereira states that the first symptoms are gastro-intestinal, such as vomiting and colic, and then cerebro-spinal symptoms come on, viz., headache, giddiness, tinnitus, confusion of sight, dilated pupils, delirium, trembling, and paralysis (Elements of Materia Medica, 1850, vol. ii. p. 977), the same effects are produced on animals. Pereira states that he did not succeed in obtaining the chemical test noted above, viz., the green alcoholic solution and the yellow resin on evaporation. Hassall figures the starch-grains of the lolium as small and something like rice; fifty or sixty may adhere together and form a compound grain not very unlike the oat. The envelopes are tolerably distinctive; the cells of the outer coat are made up of a single layer, and are disposed transversely instead of longitudinally. The second coat is in two layers, and the cells have a vertical arrangement. The third coat is like the inner coat of wheat. This account is taken from Hassall. I have not examined this grain myself.

It is not very likely that any other grains except those mentioned in the text will be mixed with wheat flour. The seeds of the Peruvian food, the *Chenopodium Quinoa* have not to my knowledge been used as a falsification. The starch-grains of the Quinoa are said to be the smallest known. It may be worth remarking that this seed is very rich in salts (4·2 per cent.), and particularly so in iron (·75 per cent.); indeed it is, I believe, the richest in iron of any vegetable. It is possible that it might be a useful food in some cases of illness. It is fairly nutritious and digestible.

The starch-grains of the acorn, which might perhaps be added in times of great scarcity, would be immediately detected, as they have a very characteristic central depression, and are also quite different in shape from the flat, round, smooth starch-cells of the wheat and barley.

The microscope alone will seldom be able to recognise added mineral matters, because these are not in very large quantity, and even in the best flour some small amount of mineral substances, derived either from the outer coats, or from the mill, can be seen. The addition of mineral matters is best determined chemically, but if it is attempted with the microscope, the gluten should be separated first; the starch should then be well mixed with water, and then allowed to subside in a conical vessel. In the lower part of the vessel the mineral matters will be found in greatest amount. If a little iodine be added to distinguish the starch-cells, the microscope may then recognise perhaps an unusual quantity of round or perhaps angular particles. If they are bone or chalk, acetic acid will dissolve them; if clay, the acid will not affect them; or the sediment, when chloroform is mixed with flour, may be examined.

green-disagreeable extract is left. Pure flour gives with alcohol only a clean straw-coloured solution, with an agreeable taste (Pellischek).

Bromus (Brome-grass—*Gramineæ;* different species—*Arvensis* or *Secalinus*).—Pellischek states that the seeds of this plant give the bread a dark colour, and make it indigestible. It is probably a most uncommon adulteration.

It will be found that when mixed with flour, the microscope will detect readily many of these substances. Detection is often very difficult when the flour is made into bread, and, therefore, whenever from the bread there is any cause of suspicion, means should be taken to obtain some of the flour.

Cones flour.—A flour obtained from Revet wheat is used by the bakers for dusting their trough. Hassall has found this Cones flour to be greatly adulterated with rice, maize, beans, rye, and barley. Sometimes Cones flour is mixed with good flour. All these impurities have been already described.

Cooking of Flour.

The effect of heat is to coagulate the albumen, and to transform some of the starch into dextrin. Substances are also added to the bread to cause a further transformation of the starch.

Cakes.—The unfermented cakes are simply made with water and salt. As they are very readily made, are agreeable to taste, and nutritious, it is very desirable to teach every soldier to make them; so that in war, when bread is not procurable, he may not be confined altogether to biscuit. The Australian "damper" is simply made by digging a hole in the ground, filling it with a wood fire, and, when the fire has thoroughly burnt up, removing it, placing the dough on a large stone, covering it with a tin plate, and heaping the hot ashes round and over it. In a campaign, every soldier, if he could get flour and wood, would soon learn to bake a cake for himself. The only point of manipulation which requires practice is not to have the heat too great; if it be above 212° too much of the starch is changed into dextrin, and the cake is tough. Exposed to greater heat, and well dried, the unfermented cakes become biscuit.

Maccaroni is flour of an Italian grain, moistened with water, and pressed through a number of small openings, while at the same time heat is applied. As it is very nutritious in small bulk, and keeps well, it would be a good food for soldiers in war if its cost could be lessened.

SUB-SECTION III.—BISCUIT.*

To make biscuit, flour is often taken with little or no bran (on account of the hygroscopic properties of bran); but bran is also sometimes used; no salt is added. The simplest biscuits are merely flour and water. Some biscuits are made with milk, eggs, &c.

Choice of Biscuit.—Biscuit should be well baked, but not burnt; of a light yellow colour, and should float in water; when struck, it should give a ringing sound; and a piece put into the mouth should thoroughly soften down. It should be free from weevils, which are easily seen.

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* Composition of Biscuit :—

Water,	8 to 12	Sugar,	1·9
Nitrogenous substances,	15	Fat,	1·3
Dextrin,	3·8	Starch,	72 to 75

Advantages as a Diet.—As it contains little water (see note, p. 216), and, bulk for bulk, is more nutritious than bread, three-fourths of a pound are usually taken to equal 1 ℔ of bread; but different authorities give different numbers. Its bulk is small, and it is easily transported.

Disadvantages.—Like flour, it is deficient in fat. After a time, it seems difficult of digestion. Perhaps the want of variety is objectionable; but certain it is, that men do not thrive well upon it for long periods. In war, it has always been a rule with the best English army surgeons, for more than a century, to issue bread as much as possible, and to use biscuit only in cases where it cannot be avoided.

Sub-Section IV.—Bread.*

If carbonic acid gas is in any way formed in or forced into the interior of dough, so as to divide the dough into a number of little cavities, bread is made.

There are three kinds of bread:—

1. Carbonic acid is disengaged by a fermentative process, caused by yeast or leaven. During the baking a certain amount of preformed sugar yields carbonic acid; a portion of starch is converted into dextrin and sugar, and also yields carbonic acid; a little lactic and butyric acids, and extractive matters are formed. It is of importance to prevent this change from going too far; and herein is one of the arts of the baker; and it is partly to prevent this that alum is added, which has the property of arresting the change (Odling).

In making bread, the proportions are 20 ℔ of flour; 8 to 12 ℔ of tepid water; 4 oz. of yeast, to which a little potato is added, and 1½ to 2 oz. of salt; 280 ℔ of flour (1 sack) will give from 90 to 105 4-℔ loaves; the baker always endeavours to combine as much water as he can, so as to get more loaves. 6½ ℔ of dough yield 6 ℔ of bread. Machines are now generally used for mixing the dough (Stevens' Machine).

2. Carbonic acid is disengaged by mixing sodium or ammonium carbonate with the dough, and adding hydrochloric, tartaric, phosphoric, or citric acids. Baking powders are compounds of these substances.

3. Carbonic acid is forced through the dough by pressure (Dauglish's patent aerated bread). This process has the great advantage of rendering it impossible that the conversion of starch into dextrin, sugar, and lactic acid shall go too far. About 20 cubic feet of carbonic acid (derived from chalk

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* Composition of Bread:—

	Water.	Nitrogenous Substances.	Fat.	Starches, &c.
English Baker's Bread:—				
Maximum nutriment,	33	8·57	1·5	56·93
Minimum nutriment,	44	6·93	1	48·07
French Commissariat:—				
Old formula,	41	7·2	1·5	47
New formula,	35	7·9	1·5	52·6
Austrian Commissariat,	45·50	6·2	1·4	46

The nitrogen in 100 parts of dry bread, in eleven different armies (examined by Poggiale), varies from 2·26 per cent. (French) to 1·12 per cent. (Prussian). In the usual English military hospital bread it is from ·9 to 1·2 per cent. of the undried bread, or 1·7 per cent. of dried bread. According to Reichenbach, the crust contains a substance (assamar), which has an influence in retarding tissue metamorphosis.

and sulphuric acid) are used for 280 lb of flour; and about 11 cubic feet are actually incorporated with the flour (Odling).

A sack of flour, containing 280 lb, will make from 90 to 105 quartern (4 lb) loaves, or 100 lb of flour will make from 129 to 150 lb of bread. If there is 14 per cent. of water in the flour, the bread will contain in the former case 33·1 per cent., and in the latter 42·7 per cent. If 100 lb of flour contain 14 per cent. of water, and make 141½ lb of bread, the bread will contain 40 per cent. of water.

Advantages of Bread as an Article of Diet.

It is hardly necessary to mention these. The great amount of nitrogenous matters and starch it shares with flour; the nitrogenous substance is to the carboniferous as 1 to 6·3 (Forbes Watson, Odling). It therefore requires more nitrogen for a perfect food. The process of baking renders it more digestible than flour. No satiety attends its use, although it may be always made in the same way; this is probably owing to the great variety of its components.

Disadvantages.—It is poor in fat and some salts, especially in the case of the finest flour freed from the internal envelope. Therefore we see that the practice of using fat with it (butter for the rich, fat bacon for the poor man) is extremely common. As to the relative advantages of the three methods of making bread, the last (aeration by carbonic acid) is said to have the advantage of making white bread, though the inner envelopes are left; of not causing any loss of starch, or permitting the change to go too far; of not containing any unwholesome yeast. The system of making bread with yeast has been objected to on the ground that bad yeast is often used; the fermentative changes go on in the stomach, much carbonic acid gas is disengaged, and dyspepsia, flatulence, and unpleasant sensations, such as heartburn, are produced. There is no doubt that badly prepared bread gives rise to these symptoms, though whether this is owing to bad yeast is, I think, uncertain. The second method yields a wholesome bread, but is too expensive for common use, and it has also been pointed out that the hydrochloric acid of commerce always contains arsenic. The amount would be too small to be hurtful, but might have a medico-legal consequence.

Special points about Making of Bread.

Bread may be of bad colour—rather yellowish, from old flour; from grown flour (in which case the changes in the starch have generally gone on to a considerable extent, and the bread contains more sugar than usual, and does not rise well), and perhaps from bad yeast. The colour given by admixture of bran must not be confounded with yellowness of this kind.

Bread is also dark-coloured from admixture of other grains, as already noticed under flour (rye, buckwheat, melampyrum, sainfoin, &c.) Bread may be acid, from bad flour giving rise to an excess of lactic and perhaps acetic acids, or, it is said, from bad yeast. It is bitter from bitter yeast.

Bread is heavy and sodden from bad yeast fermenting too rapidly, or when the fermentation has not taken place (cold weather, bad water, or some other cause, will sometimes hinder it), or when the wheat is grown; when too little or too much heat has been employed. It is said, also, that if the flour has been dried at too great a heat (above 200°), the gluten is altered, and the bread does not rise well.

It becomes mouldy rapidly when it contains an excess of water.

Rice is used as an addition because it is cheaper; it retains water, and therefore the bread is heavier. Rice bread (if 25 per cent. of rice be added) is heavier, of closer texture, and less filled with cavities. Potatoes are sometimes added, but are generally used only in small quantity with the yeast.

Alum is added to stop an excess of fermentation, when the altering gluten or cerealin acts too much on the starch, and it also whitens the bread; it does not increase the amount of water; it enables bread to be made from flour which otherwise could not be used. Sulphate of copper and of zinc, in very small amount, are sometimes employed for the same purpose.

For acid flour lime water is used instead of pure water; lime water has this advantage that, while it does not check the fermentation of yeast, it hinders the action of diastase on starch (Odling).

After being taken from the oven bread begins to lose weight. The 4-℔ loaf loses,—

In the first 24 hours, ...	$1\frac{1}{4}$ ounce.
In 48 „	5 „
„ 60 „	7 „
„ 70 „	$8\frac{3}{4}$ „

But this is merely an average, and is altered by amount of crust, temperature, and movement of air.

Loaves are generally weighed when hot, and that is considered to be their weight. In the Austrian army, a loss of 2·9 per cent. in four days is permitted.

When loaves become stale they can be rebaked, and then taste quite fresh for twenty-four hours; after that they rapidly change.

Old biscuit also, mixed with water, can be rebaked, and becomes palatable.

In the French army different kinds of bread are used:* ordinary bread; biscuited bread; bread half biscuited; bread one quarter biscuited; hospital bread. The "Pain biscuité" is used only on service; it is baked more firmly than ordinary bread.

Pain de munition ordinaire	keeps 5 days in summer and 8 in winter.
„ au quart biscuité	„ 10 to 15 days.
„ demi „	„ 20 to 30 „
„ biscuité	„ 40 to 50 „

The French munition loaf weighs 1·5 kilogrammes (3·3 ℔ avoir.), and contains two rations of 760 grammes (each 1·65 ℔). The ration of biscuit is 550 grammes (1·2 ℔).

It would be useful to adopt the practice of strongly baked bread in our army; it is a good substitute for biscuit.

Compressed Bread.—(See Concentrated Foods.)

Examination of Bread.

There is, perhaps, no article on which the medical officer is more often called to give an opinion.

General Characters.—There should be a due proportion, not less than 30 per cent. of crust; the external surface should be well baked, not burnt; the crumb should be permeated with small regular cavities; no parts should be heavy, and without these little cells; the partitions between the cavities should not be tough; the colour should be white, or brownish from admixture of bran; the taste not acid, even when held in the mouth. If the bread is acid the flour is bad, or leaven has been used; if the colour changes soon, and fungi form, the bread is too moist; if sodden and heavy, the flour is bad,

* Code des Officiers de Santé, 1863.

or the baking is in fault; the heat may have been too great, or the sponge badly set.

Chemical Examination.—This is conducted chiefly to ascertain the amount of water, acidity, and the presence of alum or sulphate of copper.

Water.—Take a weighed quantity (say 100 grains) of crumb, and dry in a water bath; powder, and then dry again in a hot-air bath or oven, and weigh; the water should not be more than 45 per cent.; if more, the bread is *pro tanto* less nutritious, and is liable to become sooner mouldy.

Acidity.—This can be determined by a standard alkaline solution. (See Beer.) At present no observations have been made on this point, but it may be important as indicating bad flour. In good bread the acidity on first baking is very trifling; it increases slightly for five or six days.

Alum.—The determination of the presence of alum is not difficult, but the quantitative analysis is a very delicate matter, and probably the medical officer will act wisely in simply noting the presence, and leaving the question of quantity undetermined. Many processes have been proposed,* some of which are merely modifications of each other. The following seems the most simple:—

1*st part.* Take at least ½ ℔ of crumb, put in a mortar, and soak it well in pure cold water; filter, and get as clear a fluid as possible; add a few drops of hydrochloric acid, and then chloride of barium. If there is no precipitate no alum can have been added, and the process need not be proceeded with. If there is a slight precipitate, it may be accounted for by sulphate of lime or magnesia in the water added, or of sulphate of magnesia in the salt, or by the slight amount of sulphuric acid naturally existing in the grain, or added during the grinding. Perhaps the medical officer will know whether the water or the salt contains sulphates, and if so, the absence of alum may be inferred. If there be a large precipitate, the presence of alum is probable, but is not certain, and the process must be continued.

2*d part.* Take another ½ ℔ of crumb, and incinerate it in an iron or porcelain vessel to black ash, or grey ash if possible. Put in an evaporating dish, add a little hydrochloric acid, and evaporate to dryness. This is in order to render as much silica as possible insoluble. Moisten thoroughly with strong hydrochloric acid, add water, and boil; filter, add sodium carbonate, nearly to neutralisation, and then an excess of pure potash dissolved in alcohol.† The lime and magnesia are thrown down; the alumina is held in solution. Boil and filter. Add an excess of hydrochloric acid, and then ammonium carbonate, and boil; alumina falls; wash the precipitate well by decantation, not using a filter, collect in a small porcelain capsule, dry, and weigh.

1 grain of alumina = 5 of dry alum.
" " = 9·4 of crystallised alum.

After weighing, to make assurance doubly sure, heat it to redness, then moisten with a few drops of nitrate of cobalt, and heat in the blow-pipe flame: a beautiful blue or purplish-blue colour should be given. As phosphate of magnesia gives the same, this test cannot be used with the ash of bread.

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* By Kuhlmann, Letheby, Odling, Wentworth Scott, Crookes, Hassall, Hadow, Horsley.

† Pure liquor potassæ is best made by taking 16 parts by weight of solid hydrate of baryta, dissolving in water, adding by degrees 9 parts by weight of potassium sulphate dissolved in water. After the barium sulphate has completely subsided, pour off the clear fluid, evaporate to dryness in a silver or platinum dish if possible, and dissolve in alcohol. Common liquor potassæ frequently contains alumina, and should be tested as follows:—Add a slight excess of hydrochloric acid, and neutralise with ammonia, boil; if a precipitate occur, the liquor potassæ must not be used. It is said also that the salt used in making bread may contain a little alumina; if so, another fallacy is introduced, and the salt must be examined; but this error must be most trifling. Whenever practicable, the flour should be obtained, and military surgeons will generally be able to do this.

There is one inaccuracy in the above process; the alumina always retains some phosphoric acid, and therefore the precipitate gives a greater quantity of alum than really exists. The difference is not probably material, but if it is, the process devised by Mr Crookes should be used,* or the following modification.

After weighing the precipitate, dissolve in nitric acid, add a piece of metallic tin, and boil; the tin is oxidised and thrown down as stannic acid and phosphate; evaporate to dryness, dissolve in water, filter, and add ammonium carbonate; pure alumina falls, dry, and weigh.†

Dr Letheby has also used a decoction of logwood as a test; a piece of pure bread and a piece of suspected bread are put in a glass containing freshly-prepared decoction, and left for twenty-four hours; the pure bread is simply stained, the alumed bread is dark purplish, as the alum acts like a mordant. Mr Hadow has also used this test with advantage, but Mr Crookes, after many experiments, came to the conclusion that it was valueless.‡ The chemical test should be therefore always resorted to.

Alum is not much used except with inferior bread.§ The amount of alum in bread is said to be, on an average, 3 ounces to a sack or 280 ℔ of flour; if the sack gives 105 4-℔ loaves, there will be 16 grains in a 4-℔ loaf; if crystallised alum is meant by this, there will be only about 8 grains of dry alum|| in a 4-℔ loaf. Hassall states the quantity to be $\frac{1}{2}$ ℔ (8 ounces) to 240 ℔ of flour, but that the quantity differs for old and new flour. A very good witness,¶ in the inquiry into the grievances of the journeyman bakers, gave the quantity at 10 ounces per sack; this would give 41·6 grains per 4-℔ loaf. When mixed with flour and baked, the alum is decomposed; part of the alumina combines most strongly with phosphoric acid; and either this or the alum itself is presumed to be in combination with the gluten; bisulphate of potash is probably formed.

The effects of alum on the flour during baking have been already noticed. The effects on health will be presently considered.

Cupric Sulphate.—Cut a smooth slice of bread, and draw over it a glass rod dipped in potassium ferrocyanide. If copper be present a brick-red colour is given by the formation of ferrocyanide of copper. This test is very delicate.

Potatoes.—If potatoes in any quantity have been added, the ash of the bread instead of being neutral is alkaline; this can only occur from sodium carbonate having been added, or from the presence of some salts of organic acid, citrates, lactates, tartrates, which form carbonates on incineration. But if it be from sodium carbonate, the solution of bread will be alkaline, so that it can be known if the alkalinity is produced during incineration. If so, it is almost certain to be from potato.

Examination of Yeast.—Common brewers' yeast is not likely to be adulterated. If any solid mineral substances are mixed with German yeast, they are detected either by washing or by incineration. Dr Letheby found German yeast, imported in 1863, to be adulterated with 30 per cent. of pipe-clay.

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* Mr Crookes' process is given in the "Chemical News," 1862.

† Article *Bread*, in "Watt's Dictionary of Chemistry," vol. i. p. 660.

‡ Chemical News, Sept. 1862.

§ Report on Journeymen Bakers, 1862, p. 164. See also Odling's Papers. Hassall, however, found alum in half the loaves examined.

|| Mitchell, in his Treatise on the Falsifications of Food, gave a much greater amount; but there is little doubt his alumina was not pure.

¶ Report on the Journeyman Bakers, 1862, p. 163. Some of the statements are beyond even this amount—1 to 4 ℔ per 1000 (4-℔ ?) loaves (p. xxxvi.); but this is probably an exaggeration.

Microscopical Examination of Bread.

Under the microscope some starch-cells can be seen, but they are generally enlarged and partly broken up; often they are broken up altogether, and form little angular masses which might be mistaken for rice starch-grains. The gluten forms little stringy masses. Sometimes with a low power some dark points are seen; under a high power, 500 or 600 diameters, these are found to be formed of a number of dark little rods joined together. This is a kind of bacterium often found in large quantities in yeast, and is carried into the bread. It must not be mistaken for an impurity.

Fungi.—The most common fungus is a kind of *Penicillium* (*silophilum* and *roseum*), greenish, brownish, or reddish yellow colour; sporules, sporangia, and mycelium can all be seen. The *Oidium aurantiacum* has been several times detected in France and Algeria; it is distinguished by its orange-red colour. A greenish mucor is often found in bread. I have not yet seen the Puccinia so common in flour.

Microscopical Examination for Adulterations.

Rice flour cannot be detected unless it is in very large quantity; then the number of small angular grains may create suspicion, often unfortunately nothing more than suspicion. Potato starch is often completely broken up, and cannot be detected; if potato itself is used, little masses of it can often be found, and some starch-grains with eccentric hilum. Incineration for the alkaline ash is useful in this case.

Bean and pea flour, if more than 4 per cent., give a dark colour to the bread; the starch cells can often be found; moistening the bread with hot water sometimes produces the peculiar smell of the pea.

The microscopical examination of bread for adulteration is unsatisfactory; the flour should be examined instead, whenever it can be obtained.

Diseases connected with the Quality of Flour and Bread.

1. *The Flour originally bad.*—It may be ergoted or grown and fermenting, or with fungi forming. An anomalous disease approaching to ergotism should lead at once to an examination of the flour. The fermenting flour produces dyspepsia and diarrhœa; the heat and moisture of the stomach, no doubt, excite at once very rapid fermentation; the gluten, already metamorphosing, acts very energetically on the starch, and carbonic acid is rapidly developed; hence uncomfortable feelings, flatulence, imperfect digestion, and diarrhœa. It is to remedy this condition of flour that alum is added, and some of the effects ascribed to alum may be really owing to the flour.

The most important disease connected with flour is, however, ergotism: this is less common in wheat than in rye flour, but yet is occasionally seen. Sometimes ergoted meal produces at once violent stomach and intestinal symptoms, at other times primary digestion is well performed, and the early symptoms are great general depression and feverishness, ushering in the local symptoms of acrodynia.

2. *Flour originally good, but altering either from age or from not having been well dried.*—The bread is often acid, and sometimes highly so; this may produce diarrhœa, though I have known such bread used for a long time without this effect; usually persons will not eat much of it, and thus the supply of nutriment is lessened. If the bread be too moist, fungi form, and the *Oidium aurantiacum*, in particular, has been known in Algiers to give rise to

little endemics of diarrhœa (Bouden and Foster).* The *Mucor mucedo* either does not produce this, or rarely. It should be remembered, however, that mouldy oats (the fungus being the Aspergillus) have given rise to paralytic symptoms in horses, so that these fungi are to be looked on with suspicion ;† and a new case of the kind has lately been reported by H. Hoffman in Giessen (Virchow's Archiv, band xliii. p. 173). Professor Varnell also states‡ that six horses died in three days from eating mouldy oats; there was a large amount of matted mycelium, and this when given to other horses for experiment, killed them in thirty-six hours; there was a "peculiar growth" on the mucous membrane of the small intestine. It is not known that the Acarus so common in flour has any bad effects when eaten.

3. *Substances added.*—Alum, of course, is the chief substance; there has been much difference of opinion as to its effects. It has been asserted to produce dyspepsia; to lessen the nutritive value of bread by rendering the phosphoric acid insoluble, and to be also a falsification, inasmuch as it permits an inferior flour to be sold for a good one. The last allegation is no doubt correct; the second probably so, as there is little doubt of the formation, and none of the insolubility, of phosphate of alumina. The first point is more doubtful, though several physicians of great authority (Carpenter, Dundas Thomson, Gibbon, Normandy) have considered its action very deleterious, and that it causes dyspepsia and constipation. Pereira considered that whatever may have been the effect in the case of healthy persons, sick persons did really suffer in that way. A question like this is obviously difficult of that strict proof we now demand in medicine, and personally I have been able to come to no conclusion. Seeing, indeed, that the usual effect of bad flour is flatulence and diarrhœa, if constipation were decidedly produced by bread, it would be more likely to proceed from alum than from any other ingredient of the bread. Looking again to the fact that sometimes bread has contained large quantities of alum,—sometimes as much as 40 grains in a 4-℔ loaf, and probably more,—we get an amount in an ordinary meal which (if the aluminium phosphate is an astringent) might very well cause constipation. Looking, then, to the positive evidence, and the reasonableness of that evidence, it seems to me extremely likely that strongly alumed bread does produce the injurious effects ascribed to it.

The addition of alum is forbidden by law.

Sulphuric acid is said to be added§ before grinding instead of alum ; it has the same power of preventing decay.

As already stated, lime water may be used, and with advantage.

Sulphate of Copper.—The amount used is so small that it seldom produces any symptoms; still it is possible that some anomalous cases of stomach irritation might be owing to this.

The *Lolium temulentum* gives rise to narcotic symptoms (see *ante.*)

Flour from other Grains.—It is not known whether the addition of potatoes, rice, barley, peas, &c., in any way injures health, except as it may affect nutrition or digestion. Occasionally, in times of famine, other substances are mixed—chestnuts, acorns, &c. In 1835, during famine, fatal dysentery appeared in Königsberg, owing to the people mixing their flour with the pollen of the male catkin of the hazel bush. In India the use of a vetch, *Lathyrus sativus* (kessaree-dholl), with barley or wheat, gives rise to a special paralysis

* Archives Gen. de Méd., 1848, p. 244.
† Sanderson's Report in Syd. Soc. Year-Book for 1862, p. 462.
‡ Journal of the Society of Arts, April 1865.
§ Dr Angus Smith, Annual Report of the Manchester and Salford Sanitary Association for 1863.—Report of Sub-Committee.

of the legs, when it exceeds $\frac{1}{12}$th part of the flour (Irvine in "Indian Annals"); the *L. cicera* has the same effect.*

SECTION III.

BARLEY.†

As an article of diet barley has the same advantages and disadvantages as wheat. It is said to be rather laxative (Pereira), and I have myself noticed that either from this cause, or from the imperfect separation of the sharp husks, barley bread is particularly unsuited for dysenteric cases. It is certainly, however, very nutritious, and the Greeks trained their athletes on it. Its richness in phosphoric acid and iron render it particularly adapted for this.

Choice of Barley.—(Scotch or pot barley, viz., the grain without the husks.) For the barley grains the same points are to be attended to as in wheat.

For the pearl barley (which is merely the grain rounded off), the best tests are the physical characters, colour, freedom from dust, grit, and insects, and the test of cooking.

The patent prepared or powdered barley should be examined with the microscope; any kind of cheaper grain may be mixed with it. For figures of barley see pages 206–208.

Diseases arising from altered quality.—These are the same as those of wheat—viz., indigestion, flatulence, and diarrhœa. I am not aware that there is anything peculiar in the action of diseased barley as distinguished from wheat.

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* Dr Irvine has lately ("Indian Annals," Jan. 1868) again described the symptoms produced by the kessaree-dholl or Lathyrus. The first symptoms are gastro-intestinal irritation, and the paraplegia follows on this.

† *Analysis of Barley Meal and Bran in* 100 *parts* (*Von Bibra*).

	In the Meal (salts omitted).	In the Bran (salts omitted).
Water,	15	12
Albumen,	1·634	1·740
Substances indicated in the term Gluten,	11·347	13·103
Gum,	6·744	6·885
Sugar,	3·200	1·904
Fat,	2·170	2·960
Starch,	59·950	42·008
Cellulose,	...	19·400

Mineral substances in 100 *parts of Barley freed from husks. The husks contain large quantities of silicates* (*Von Bibra*).

Percentage of ash in the flour,	2·53
Potash,	24·36
Soda,	3·64
Magnesia,	9·59
Lime,	3·54
Phosphoric acid,	49·40
Sulphuric acid,	2·75
Silicate of alumina,	5·49
Oxide of iron and loss,	1·33
	100·00

SECTION IV.

OATS.*

Oats have been considered even more nutritious than wheat or barley, and, certainly, not only is the amount of nitrogenous substance great, but the proportion of fat is large. Unfortunately, the absence of gluten in the nitrogenous substance takes away the adhesive property, and bread cannot be made; the amount of indigestible cellulose is large. But, on the other hand, oatmeal has the great advantage of being very readily cooked, much more so than wheat or barley.

For this reason, and because it contains much nutriment in small bulk, because it can be eaten for long periods with relish, and keeps unchanged for a long time, it would seem to be an excellent food for soldiers during war—an opinion which does not lose in force, when we remember that it formed the staple food of one of the most martial races on record, the Scotch Highlanders, whom Jackson considered also one of the most enduring. Formerly, when oats were badly cleaned, intestinal concretions of the husk and hairs were common among those who lived on oatmeal, but these are now uncommon. It has been thought to be "heating" when taken continually, but this is probably a prejudice.

Adulterations.—Barley-meal and the husks of barley, of wheat, and of oat itself, are added very frequently. A single look through the microscope detects the round and smooth barley starch; the envelopes are recognised with very little more trouble. Rice and maize are also sometimes used. The drawings already given will also enable these substances to be detected. Hassall found about half the samples of oatmeal adulterated.

Choice of Oatmeal.—There should be a good proportion of envelope, but no branny character, which usually arises from barley husks; the starch should not be discoloured. A microscopic examination should always be made, both for adulterations and Acari.

SECTION V.

MAIZE AND RYE.†

Both these grains are very nutritious; maize contains a large quantity of

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* *Oatmeal—in* 100 *parts after* (*Von Bibra*).

Water,	12·330	Sugar,	2·243
Albumen,	1·524	Fat,	6·829
Other nitrogenous substances,	14·547	Starch,	59·027
Gum or Dextrin,	3·500		

It is possible that this analysis gives too much nitrogenous substance; the mean of other statements, indeed, gives 13·6 of nitrogenous substance, 69 of starch and sugar, 5·6 of fat, 2·86 of salts, 12·5 water, and the rest cellulose.

The quantity of fat is very great in oats. The fat is brown-yellow, and more fluid than that of wheat or barley. The mineral constituents are very much the same as in the other Cerealia. A small portion of the nitrogenous has been called avenin by some; it corresponds to the casein of Von Bibra.

† *Maize* (*Indian Corn—called Mukka in India*)—*in* 100 *parts* (*Poggiale*).

Water,	13·5	Starch and Dextrin,	64·5
Nitrogenous substance,	9·9	Cellulose (from the bran),	4·0
Fat,	6·7	Ash,	1·4

The amount of fat is very great.

In 100 *parts of Ash* (*Stepf.*).

Potash,	28·80	Lime,	6·32
Soda,	3·50	Phosphoric acid,	44·97
Magnesia,	14·90	Iron, sulphuric acid, and loss,	1·51

yellowish fat (6 to 7 per cent.) It requires very careful cooking, as otherwise much passes out undigested.* My friend, Dr Johnston, has communicated to me the particulars of an outbreak of diarrhœa in a military prison clearly due to badly cooked maize. It should be soaked in water, but not too long (two to four hours), and then thoroughly boiled for several hours (four to six) at a rather low heat. Maize cakes are both palatable and nutritious.

Rye makes a very acid dark bread, which causes diarrhœa in those unaccustomed to it; custom, however, soon remedies this, and, as far as nutritive value goes, it appears equal to wheat. It contains less vegetable fibrine, and more casein and albumen, and a peculiar odorous substance.

Diseases connected with Maize and Rye.

It is presumed that alterations in the flour will produce the same diseases as in the analogous case of wheat. Ergotism is, however, more common in rye than any other grain. The Pellagra of Lombardy has been ascribed to a fungus (Verderame or Verdet) forming in the maize. Many volumes, with different statements, have been written on this point, and it is still doubtful whether or not the Verdet has this effect. The evidence is not sufficient, but, on the whole, seems to me most in favour of the view which connects Pellagra with diseased maize.

SECTION VI.

RICE.†

The whole grain (paddy) deprived of the husk is sold as rice. There are many varieties, of different colours (white, red, brown?) and composition. The amount of nitrogenous matter varies greatly, from 3 to 7·5 per cent. of the moist grain. As an article of diet, it has the advantage of an extremely

In 100 parts of Rye-flour and Rye-bran (Von Bibra).

	Flour with little Bran.	Bran.
Water,	14·6	15·320
Albumen,	1·565	2·150
Substances included under gluten,	10·191	15·941
Gum or Dextrin,	4·100	10·400
Sugar,	3·465	1·860
Fat,	1·800	4·720
Starch,	64·289‡	21·085
Cellulose,	...	28·533

For the salts, see the other table.

Amount of Ash in 100 of Rye-flour = 2.—*In 100 of Ash (Von Bibra).*

Potash,	29·37 to 37·54
Soda,	3·35 to 0·300
Magnesia,	10·77 to 14·37
Lime,	1·34 to 2·63
Phosphoric acid,	50·35 to 42·
Silicate of alumina,	1·44
Oxide of iron, and sulphuric acid,	2·38

* See especially on this point, Edward Smith's "Experiments on Prisoners in Colbath-fields." The food was partly maize, and 40 or 50 grains of nitrogen were passed daily by the bowels, no doubt from undigested food.

† *Rice-flour (Von Bibra), in 100 parts (without salts).*

Water,	14
Albumen,	0·050
Other nitrogenous matters,	7·192
Gum or Dextrin,	1·570
Sugar,	0·390
Fat,	0·900
Starch,	75·918
	100·000

The amount of nitrogenous substance is greater than usual. The salts amount to from ·3 to ·85 per cent.; potash, magnesia, and phosphoric acid are the main ingredients, as in the other Cerealia.

‡ A little cellulose still with the starch.

digestible stareh-grain, and, like the other Cerealia, there is a great admixture of substanees; it is, however, poorer in nitrogenous substanees than wheat, and is mueh poorer in fat, eonsequently, among riee-feeding nations, leguminous seeds are taken to supply the first, and animal or vegetable fats to remedy the latter defeet. Riee is also poor in salts.

Cooking of Rice.—It should properly be steamed, not boiled, and the steaming should be thoroughly done, else the starch-grains are not swollen and digestible. If boiled, it should be for a long time at a low temperature; the riee (or eonjee) water eontains some albuminous matter, and the grain loses in nutritive power.

Choice of Rice.—The grains should be elean, without grit; the individual grains without spots, or evidenee of inseets. The size varies mueh, aeeording to the kind; the large kinds usually command the highest market priee.

Comparison of the foregoing Grains—Order of Richness.

Nitrogenous Substances.	Fat.	Starch, &c.	Salts.
Wheat.	{ Maize.	Riee.	Barley.
Barley.	{ Oats.	Maize.	Oats.
Rye.	Barley.	Wheat.	Wheat.
Oats.	Rye.	Rye.	Rye.
Maize.	Wheat.	Oats.	Maize.
Riee.	Riee.	Barley.	Riee.

SECTION VII.

MILLET, RAGGY, BUCKWHEAT, GRAM.

Various other grains belonging to the Cerealia, or to other natural orders, but having similar properties, are used as food in different eountries. Of these, the above named are ehiefly those the medieal offieer may have to report on.

Millet is used largely in Afriea (west eoast), and Algeria, in Italy, Spain, Portugal, some parts of India, China, &e.

English Names.	Botanical Names.	Indian Names.
Common millet,	Panieum miliaeeum,	Sawee Chennawaree (Hindustani). Varagoo (Tamul).
Small millet,	Sorghum or Panieum vulgare,	Dhurra (Arabie). Cholam (Tamul). Joar or Jowree (Hind.).
Spiked millet,	Penieillaria spieata,	Bájra or Bajree (Hind.). Cumboo (Tamul).
Golden-eoloured millet,	Sorghum saeeharatum.	
Italian millet,	Setaria Italiea,	Kala kangnī (Hind.). Tenay (Tamul).
German millet,	Setaria Germaniea.	
	Eleusine coroeana,	Ragee or Raggy (Hind., Canarese, and Tamul). Murha and Maud in the N. Prov. of Hindustan.

The table sufficiently expresses the composition of most of these.*

In 100 parts of Meal (freed from Bran).

	Panicum miliaceum (Common Millet).	*Penicillaria spicata*; a kind of Millet much used in India under the name of Bajra.	*Sorghum vulgare*, Dhurra of the Arabs, Joar or Jowaree of India.
Water,	12·22	11·8	11·95
Nitrogenous substances,	9·27	10·13	8·64
Dextrin,	9·13	...	3·82
Sugar,	1·80	...	1·46
Fat,	7·43	4·62	3·9
Starch,	59·04	71·75	70·23 { with husks.
Silica,	0·11	...	...

The ash is about 3 per cent. in Panicum, 2·6 in Penicillaria, and 1·7 in Sorghum. When freed from silica, which is present in large amount, the ash contains 20 per cent. of potash, 24 of magnesia, a little soda, no lime, and about 50 per cent of phosphoric acid.

The other millets (*Setaria germanica* and *Panicum sanguinale*) are very similar in constitution.

Millet bread is very good, and some was issued to the troops in the last China Expedition. This should always be done in a millet country, if wheat or barley cannot be got.

Raggy or Ragee, Murha and Maud of the upper provinces (*Eleusine coro-cana*), a millet, is largely used in Southern India (Mysore), and in some parts of Northern Hindustan, and is considered even more nutritive than wheat.† It is very indestructible, and can be preserved for many years (even sixty) in dry grain-pits.

Buckwheat and Gram are not so likely to be used. The former is poor in nitrogenous substances and fat, but makes a fair tasting bread.

Gram bread or cakes have been occasionally used in India for Europeans, and this use might be extended; the cakes are palatable, and extremely nutritious, as may be seen by the tables.

Polygonum Fagopyrum, or *Fagopyrum esculentum*‡ (Buckwheat), used in some parts of Russia, Germany, and France.

In 100 parts.

Water,	12·754	Sugar,	0·914
Nitrogenous substances,	2·645	Fat,	0·943
Dextrin,	2·850	Starch,	79·894

The ash is about 1·09 per cent., and contains chiefly potash, magnesia, and phosphoric acid.

Cicer arietinum (Gram or Gram-Dholl of India).

In 100 parts without husk.

Water,	11·39	Starch,	63·18
Nitrogenous matters,	22·70	Mineral matter,	2·60
Fat,	3·76		

* The native names of the Indian grains and pulses used, especially in Southern India, are given very fully in a paper by Mr Elliot (*Edinburgh Philosophical Journal*, July 1862): and also in Mr Cornish's excellent paper (*Madras Medical Journal*, February 1864).

† For the Indian grains and pulses, Dr Forbes Watson's admirable paper can be consulted; also the papers by Mr Elliot and Dr Cornish already referred to.

‡ Other species of Buckwheat are *P. tartarium* and *P. emarginatum*.

SECTION VIII.

LEGUMINOSÆ.*

The Leguminosæ, in respect of dietetic properties, are broadly distinguished from other vegetables by their very large amount of nitrogenous substance, called legumin or vegetable casein. The advantages of peas and beans as articles of diet are the great amount of this substance, and the existence of much sulphur and phosphorus in combination with the legumin; in salts also they are a little richer than the Cerealia, especially in potash and lime, but are rather poorer in phosphoric acid and magnesia; 1 lb of peas contains about 168 grains of salts. The disadvantages of peas and beans are a certain amount of indigestibility; about 6·5 per cent. of the ingested pea passes out unchanged, and starch-cells, giving a blue reaction with iodine, are found in the fæces; much flatus is also produced by the sulphuretted hydrogen formed from the legumin. Still, they are a most valuable article of food, and are always to be used when much exercise is taken, as they are an excellent addition to meat and Cerealia. Both men and beasts can be nourished on them alone for some time. Added to rice, they form the staple food of large populations in India.† Mr Cornish mentions that, in the Sepoy corps, the

* Composition of Dried Grain :—

	Pisum sativum—Peas.	*Phaseolus vulgaris*—Kidney Bean.	*Vicia Faba*—Common or Broad Bean.
Water,	14·5	16	12·8
Legumin, albumen, and gluten-like substances,	22·3	22·5	22
Cellulose,	4·9	4·4	5
Starch and Dextrin and Sugar,	52·6	49·9	52·6
Fat,	2	2	1·6
Chlorophyll,	1·2	...	...
Salts,	2·4	2·4	2·5
Potash,	·86	·98	·62
Soda,	·16	·24	·34
Lime,	·1	·23	·15
Magnesia,	·18	·18	·2
Iron,	·023	·001	·03
Phosphoric acid,	·85	·64	·9
Sulphuric acid,	·077	·07	·08
Chloride of potassium,	·067	...	...
Chloride of sodium,	·044	...	...
Chlorine,	...	·025	·06

† Chief Indian Peas and Beans (after Forbes Watson), in 100 parts (without husks):—

	Pisum sativum—Analysis of Indian Pea, Bombay and Bengal (Buttanee, Hindustani).	*Cajanus indicus*—A Pea called Dhollor Toor-dholl in India.	*Phaseolus*—Ooreed of India.	*Soja hispida* — (A Bean) Bhoot of India.	*Dolichos*—(A Bean) Wall or Ghot-wall or Cooltee of India.	*Ervum Lens*—Lentil, called Dholl, like the Cajanus, or Mussoor in Hindustani.‡
Water,	11·79	10·63	12·44	10·25	12·03	11·84
Nitrogenous substances,	27·96	22·18	24·73	38·83	23·27	25·15
Fat,	1·47	1·95§	1·36	10·51	2·20	1·26
Starch,	56·36	62·13	58·76	26·65	59·38	59·85
Mineral Matters,	2·48	3·11	3·17	4·14	3·19	1·92

‡ Not liked by the Hindus, on account of its red blood-like colour.

§ A little oil is often mixed with the Dholl, which increases the fatty matter to 3 or 4 per cent.

men are much subject to diarrhœa from the too great use of the "dholl" (*Cajanus indicus*).

Choice of Pea.—By keeping, peas lose their colour, become very pale and much shrivelled, and extremely hard. Anything like decomposition, or existence of insects, is at once detected. The powder does not keep very long; the whole peas should be split.

The microscope should be used to detect the Acarus. The characters of the *Pea* and *Bean Starch* are given at page 211.

Cooking of Peas and Beans.—They must be boiled slowly, and for a long time, otherwise they are very indigestible. If old, no amount of boiling softens them; in fact, the longer they are boiled the harder they become; they should then be soaked in cold water for twenty-four hours, crushed, and stewed; in this way even very old peas may be made digestible and palatable. Chalk-water must be avoided in the case of peas as of other vegetables, as the lime-salts form insoluble compounds with the legumin.

Lathyrus sativus (Kassaree-dholl of India).—Occasionally in Europe, and constantly in some parts of India, this vetch has been used when mixed with wheat or barley flour for bread. When used in too great quantities, it produces (without there being necessarily any alteration of the grain?) constipation, colic, and some form of indigestion, and if eaten in large quantity, paraplegia. It is also injurious to horses, but less so to oxen. In Bengal, Dr Irving* found in some villages no less than from 10 to 15 per cent. of the people paralytic from this cause.

From its composition, it would not appear to be innutritious. Without husks, it is composed of—

Nitrogenous substances,	27·96	Ash, ...	2·48
Fat, ...	1·47	Water, . . .	11·72
Starches, . . .	56·30		

SECTION IX.

SUCCULENT VEGETABLES.

Almost all other vegetables are used, not so much on account of nutritive qualities, as for the supply of salts; some of them, however, contain very digestible starch and sugar, or other substances, such as pectin or asparagin, or peculiar oils which act as condiments, as in onions.

Sub-Section I.—Potatoes (Solanum Tuberosum).

The composition has been already given (p. 165). The salts are noted below.† It will be observed from these, and from the tables already given, that the

* Indian Annals, 1857. Ibid., Jan. 1868, p. 89, Dr Irving notices the resemblance of the symptoms to the Barbiers of Bontius.

† *Potato.*—Percentage amount of ash 1· to 1·5. Mineral constituents in 100 of ash.

	(Way.)	(Fromberg.)
Potash, . . .	46·60	50·23
Soda, . . .	...	3·7
Magnesia, . .	8·70	4·4
Lime, . . .	4·54	0·83
Phosphoric acid, .	13·30	10·10
Sulphuric ,, .	4·66	14·67
Chloride of potassium,	...	11·76
Chloride of sodium,	3·43	...
Carbonic acid (from the incineration of organic acids),	13·30	...
Oxide of iron, .	?	...
Silicate of alumina,	1·95	...

The carbonate of potash is produced in the incineration from the vegetable salts (citrate, malate, tartrate of potash). An analysis of Vogel's gives no less than 21 per cent. of carbonate of potash, and 34 per cent. of carbonate of soda in 100 of ash.

amount of potash and phosphoric acid is not so great as in some other substances; the true use of the potato is probably to be found in the large amount of salts (malates? tartrates? citrates) which form carbonates on incineration. The juice of the potato is acid. There is no better anti-scorbutic than the potato, and its starch is very digestible. The citric acid is combined with potash, soda, and lime.

As the amount of salts is small, and that of water large, at least 8 to 12 ounces of potatoes should be taken daily if no other vegetables are eaten (= 8 ounces at 1 per cent. of salts contain 35; at 1·5 per cent. = 52·5 grains).

Choice.—Potatoes should be of good size, firm, cut with some resistance, and present no evidence of disease or fungi.

A still better judgment may be formed by taking the specific gravity, and using the following tables:—

Potatoes.—The solids can be determined by taking the specific gravity, and multiplying it by a factor taken from the table below, the result is the percentage of solids:—

Specific gravity, between	Factor.	Specific gravity, between	Factor.
1061—1068	16	1105—1109	24
1069—1074	18	1110—1114	26
1075—1082	20	1115—1119	27
1083—1104	22	1120—1129	28

If the starch alone is to be determined, deduct 7 from the factor, and multiply the specific gravity by the number thus obtained, the result is the percentage of starch.

If the specific gravity of the potato is—

Below	1068	The quality is very bad.
Between	1068—1082	„ inferior.
Between	1082—1105	„ rather poor.
Above	1105	„ good.
Above	1110	„ best.

As, however, the medical officer will seldom have an hydrometer which will give so high a specific gravity, and must work, therefore, with a common urinometer, the following plan must be adopted:—Take a sufficient quantity of water, and dissolve in it ½ an ounce or an ounce of salt, and take the specific gravity; then add another ½ ounce or ounce, and take again the specific gravity; do this two or three times, so as to get the increase of specific gravity for each addition of a known quantity of salt; then add salt enough to bring up the specific gravity to the desired amount. This is, of course, not quite accurate, but in the absence of proper instruments it is the only plan I can devise.

Cooking of Potatoes.—The skins should not be taken off, or a large amount of salts passes into the water; using salt water is a good plan, as fewer of the salts then pass out. The boiling must be complete, as the starch-grains are otherwise undigested, and it must be slow, else the cellulose and albuminates are hard. Steaming potatoes is by far the best plan; the heat must be moderate; the steam penetrates everywhere, and there is no loss of salts.

Preservation of Potatoes.—Sugar, in the form of molasses, is the best plan on a large scale; a cask is filled with alternate strata of molasses and peeled and sliced potatoes. On a small scale, boiling the potatoes for a few minutes

will keep them for some time. Free exposure to air, turning the potatoes over and at once removing those that are bad, are useful plans.*

The preserved potatoes are sliced, dried, and granulated, and when well prepared, are extremely useful.

SUB-SECTION II.—SWEET POTATO (CONVOLVULUS BATATA).

Composition per cent.—

Water,	67·5 to 73	Albumen,	1·5
Starch,	13 to 16	Fat,	·3
Sugar,	6 to 10	Salts,	2·9
Pectic acid,	1·2	Cellulose,	2·5

This vegetable is very rich in sugar and in salts. It may be usefully employed for soldiers, wherever it can be procured, in lieu of potatoes, for some time.

SUB-SECTION III.—YAM (DIOSCOREA SATIVA).

Composition—

Water,	74	Pectin,	2·8
Albuminates,	2	Cellulose,	2·2
Starch,	16	Fat,	·5
Sugar,	·2	Salts,	1·3

This also is a useful vegetable, though inferior to the potato and batata. It is largely used for soldiers in the West and East Indies.

SUB-SECTION IV.—OTHER VEGETABLES.

The composition of Carrots and of Cabbage has been already given (p. 165). Two or three of the more common may be added—

	Water.	Albumen and Casein.	Starch, Sugar, and Dextrin.	Fat.	Woody Fibre.	Mineral Substances.
Turnip (*Brassica rapa*),	90·5	1·1	4·0	...	2·4	0·5
Parsnip (*Pastinaca sativa*),	82·04	1·215	6·389	0·546	8·022	1·041
Jerusalem artichoke (*Helianthus tuberosus*),	76·35	0·9	19	0·9	1·22	1·61

Other vegetables contain special ingredients, such as asparagin in asparagus (a small amount is also contained in potatoes), wax, pectin, which is a little more oxidised than starch or sugar; or peculiar oils and savoury or odoriferous matters.

On account of its volatile oils, the onion tribe is largely used, and is a capital condiment, and has an effect as an anti-scorbutic.

Onion contains some citrate of lime (for Dried Vegetables, see page 249).

There are many vegetables which can be employed as anti-scorbutics besides potatoes, onions, and green vegetables. The wild artichoke, the *Agave americana* (cactus), are both excellent anti-scorbutics, and the latter is said to

* In the Crimean war there was a considerable loss of potatoes sent up to Balaklava, and at a time when the men were most in need of them. The addition of sugar to the raw potatoes might have been made.

be better than lime juice. Sorrel, and in a less degree scurvygrass and mustard and cress are useful. In New Mexico a salad made of the "lamb's quarter" (*Chenopodium album*), was found very useful.*

In war almost any kind of vegetables may be used rather than that the troops should be left without such food. In one of the Caffre wars, an African corps kept free from scurvy by using a sort of grass (?) in their soup.

The dried vegetables, and especially the dried potato, have considerable anti-scorbutic powers (Armstrong).† The dandelion was largely used in the French army in the Crimean war. The American Indians put up for winter quantities of dried plums, buffalo berries, and choke berries, and escape scurvy (*Hamilton's Mil. Surg.* p. 212).

If vegetables cannot be procured, citrate, tartrate, and lactate of potash should be given.

SECTION X.

COW'S MILK.

A cow gives very variable quantities of milk, according to food and race, and age of the calf; perhaps 20 to 25 pints in twenty-four hours is the average for the year, but with poor feeding it will fall much below this; occasionally a cow, soon after calving, will give 50 pints, but this is not common. A goat will give 6 to 8 pints.

Sub-Section I.—Milk as an Article of Diet.

Milk contains all the four classes of aliment essential to health. Being intended especially for feeding during growth, the proportions of nitrogenous substances and fat, as compared to sugar, are large.

Average composition of unskimmed milk.—A certain proportion between the casein, fat, and sugar must exist.

	Per cent. Specific Gravity, 1030.	Per cent. Specific Gravity, 1026.		Per cent. Specific Gravity, 1030.	Per cent. Specific Gravity, 1026.
Casein, . . .	4	3	Salts, . . .	·6	·5
Fat, ...	3·7	2·5	Total solids,	13·3	9·9
Lactin, . . .	5	3·9	Water, . .	86·7	90·1

The casein is by some supposed to be a combination of albumen with potash (Hoppe-Seyler).

In addition to casein, a small quantity of true albumen remains in solution after the casein has been thrown down, and there is also, according to Millon,‡ another albuminoid substance, which he calls lactoprotein. In cow's milk the amount of albumen is said to be 5·25 grammes per litre; the amount of lactoprotein is much smaller, but has not been very precisely determined.§

The amount of salts (see page 167) varies from ·5 to ·8 per cent., but seldom, if ever, exceeds 1 per cent. This is of importance in the detection of adulteration by salts. In poor milk the salts may be as low as ·3 per cent.

Milk is very largely used in some countries, especially in India and Tartary,

* Mil. Med. and Surg. Essays prepared for the U. S. Sanitary Com. 1864, p. 202.

† Naval Hygiene, p. 112. In the American war, however, the anti-scorbutic effects of the dried vegetables were not found to be very great.

‡ Comptes Rendus, t. lix. p. 396.

§ Commaille (Comptes Rendus, Nov. 9, 1868) found creatinine in some putrid milk, derived, he thinks, from creatin. He admits also, after Lefort, that there is a little urea. He found also some organic acids, the nature of which is doubtful.

where the use of the koumiss, prepared from mare's milk, has been supposed to prevent phthisis.

Milk varies in quantity and composition according to—1*st*, the age of cow; 2*d*, the number of pregnancies, less milk being given with the first calf (Hassall); 3*d*, to the age of the calf, being at first largely mixed with colostrum; 4*th*, to the time of day, being slightly richer in solids in the morning (Hassall); 5*th*, to the kind of feeding, beet and carrot augmenting the sugar;* 6*th*, and remarkably, according to the race, some cows giving more fat (as Alderneys), others more casein (as the long-horns). The last portion of the milk given in milking is richest in cream (Hassall).

The goat's milk is rather richer in solids (14·4 per cent.—Payen), and contains also a peculiar smelling acid (hircine or hircic acid). Specific gravity, 1032–1036.

Ass's milk is rather poorer in solids (9·5 per cent.—Payen). This is owing to a small amount of casein and fat; it is rich in lactin. The specific gravity varies from 1023 to 1035.

The buffalo milk is richer in all the ingredients.

Taking the total solids of cow's milk at only ten per cent. (specific gravity 1026), one pint (20 ounces) will contain, in round numbers—

Casein,	262 grains.
Fat,	217 ,,
Lactin,	341 ,,
Salts,	43 ,,
Total,	863

or very nearly 2 ounces avoir. of water-free food.

To give 23 ounces of water-free food (or one day's allowance for an adult), rather more than 11 pints of milk, of specific gravity 1026, are necessary. For an adult this would be far too much water, and the fat would be in great excess. But for the rapid formation and elimination of the young, the water and fat are essential. It is a question whether, in old age, large quantities of milk might not be a remedy for failures in tissue formation and elimination.†

Sub-Section II.—Alterations of Milk.

The cream rises in from four to ten hours; it is hastened by adding warm water, but its quantity is not increased (Hassall).

Milk alters on standing; it absorbs oxygen, and gives off carbonic acid; placed in contact with a volume of air greater than its own bulk, it absorbs all the oxygen in three or four days (Hoppe-Seyler). The carbonic acid is formed at the expense of the organic matter (probably casein—Hoppe-Seyler), and bodies richer in carbon and hydrogen are formed; fat increases in amount, and oxalic acid is said to be formed.

Subsequently lactic acid is formed in large quantities from the lactin; the milk becomes turbid, and finally casein is deposited. The cream which had previously risen to the surface disappears.

Milk given by diseased Cows.

Milk from diseased animals soon decomposes; it may contain colostrum, or heaps of granules collected in roundish masses, pus cells, or epithelium, and

* Some observations of Dr Ssubotin (Virchow's Archiv, band xxxvi. p. 561) on the milk of bitches, show a marked effect by food; the fat was much increased by meat; the casein was less affected; a large quantity of fat greatly lessened the secretion.

† This was a point debated by Galen, so old is this suggestion. It is still undecided. Some old persons cannot digest milk.

occasionally blood. It then soon becomes acid, and the microscope detects usually abnormal cell forms, and casts of the lacteal tubes.

Sub-Section III.—Examination of Milk.

This is intended first to determine the quality. Put some of the milk in a long glass, which is graduated to 100 parts; a 100 centimetre or litre measure will do, or a glass may be specially prepared by simply marking with compasses 100 equal lines on a piece of paper, and gumming it on the glass. Allow it to stand for twenty-four hours. By this means the percentage of cream can be seen, and the presence of deposit, if any, observed. There should be no deposit till the milk decomposes; if there be, it is probably chalk or starch.

The cream should be from $\frac{6}{100}$ths to $\frac{11}{100}$ths; it is generally about $\frac{8}{100}$ths; in the milk of Alderney cows it will reach $\frac{30}{100}$ths or $\frac{40}{100}$ths. The time of year (as influencing pasture), and the breed, should be considered.

While this is going on, determine—

1. *The Physical Characters.*—Placed in a narrow glass, the milk should be quite opaque, of full white colour, without deposit, without peculiar smell or taste. When boiled it should not change in appearance.

2. *Reaction.*—Reaction should be slightly acid or neutral, or very feebly alkaline; if strongly alkaline, either the cow is diseased (?) or there is much colostrum, or carbonate of soda has been added.

3. *Specific Gravity.*—The specific gravity varies from 1026 to 1035. A very large quantity of cream lowers it, and after the cream is removed, the specific gravity may rise. The average specific gravity of unskimmed milk may be taken as 1030 at 60° Fahr., and the range is nearly 4° above and below the mean.

The addition of water is best detected by the specific gravity. No doubt the method is not perfect, but its ease of application strongly recommends it. The following table shows the specific gravity at 60°, with the addition of different quantities of water, as determined by several experiments :—

	Specific Gravity.	Specific Gravity.
Original specific gravity, . .	1030·5	1026
9 milk, + 1 water, . .	1027	1023
8½ ,, 1½ ,, . . .	1025	...
8 ,, 2 ,, . . .	1024	1019
7 ,, 3 ,, . . .	1021	1017·5
6 ,, 4 ,, . . .	1018	1016
5 ,, 5 ,, . . .	1015	...

4. *Examine chemically for the Amount of the Different Constituents*—

(*a.*) *Total solids.*—Evaporate a known weight to dryness, and weigh. Calculate the percentage. The heat must not exceed 240° Fahr. As it is difficult to dry it thoroughly, the result is only approximative. A known quantity of barium sulphate may be added to separate the particles, and facilitate the drying.

(*b.*) *Ash.*—Incinerate the total solids, and weigh.

(*c.*) *Casein.*—Take a weighed or measured quantity; add two or three drops of acetic acid, and boil. Add a good deal of water; allow to stand for twenty-four hours; pour off the supernatant fluid; wash the precipitate well with ether at 80°; dry, and weigh. Calculate the percentage. It is difficult to entirely free it from fat.

(*d.*) Evaporate the ether, and weigh the fat. This requires care, however, and the same result can be given by the employment of an instrument called

a lactoscope, which measures the degree of transparency. The lactoscope of Donné has been lately improved by Vogel, and this simple plan can be recommended for ascertaining the amount of fat in milk.

Vogel's instrument consists of a little cup, formed by two parallel pieces of glass, distant $\frac{1}{2}$ a centimeter (= ·1968 inches, say $\frac{2}{10}$ths of an inch) from each other, and closed everywhere except at the top, so as to form a little vessel; a glass graduated to 100 C.C., and a little pipette, which is divided to $\frac{1}{2}$ C.C., are also required. Water (100 C.C.) is placed in the measure, and 2 or 3 C.C. of milk (which should be first agitated, so as to mix any separated cream) are added to it. The parallel glass cup is then filled with this diluted milk, and a candle placed about one metre from the eye (= 39·37 inches) is looked at; if the candle is seen, the milk is poured back into the large measure; more milk is added to it, and it is poured again into the parallel glass, and the light is again looked at; the experiment ends when the contour of the light is completely obscured. The candle should be a good one, but the difference in the amount of light is not material. The percentage amount of fat in the milk is then calculated by the following formula (which has been determined by a comparison of the results of the instrument, and of chemical analysis): x being the quantity of fat sought; and m the number of C.C. of milk, which added to the 100 C.C. of water, suffice to obscure the light.

$$x = \frac{23 \cdot 2}{m} + 0 \cdot 23.$$

If, for example, 3 C.C. of milk, added to the 100 of water, were sufficient to obscure the light, the percentage of fat is—

$$x = \frac{23 \cdot 2}{3} + \cdot 23 = 7 \cdot 96 \text{ per cent.}$$

From this formula the following table has been calculated, which enables us to read off at once the percentage of fat:—

C.C. Milk.		=	Per cent. of Fat in the Milk.	C.C. Milk.		=	Per cent. of Fat in the Milk.
1	to 100 of water	obscures the light	=23·43	14	to 100 of water	obscures the light	=1·88
1·5	”	”	15·46	15	”	”	1·78
2	”	”	11·83	16	”	”	1·68
2·5	”	”	9·51	17	”	”	1·60
3	”	”	7·96	18	”	”	1·52
3·5	”	”	6·86	19	”	”	1·45
4	”	”	6·03	20	”	”	1·39
4·5	”	”	5·38	22	”	”	1·28
5	”	”	4·87	24	”	”	1·19
5·5	”	”	4·45	26	”	”	1·12
6	”	”	4·09	28	”	”	1·06
6·5	”	”	3·80	30	”	”	1·00
7	”	”	3·54	35	”	”	0·89
7·5	”	”	3·32	40	”	”	0·81
8	”	”	3·13	45	”	”	0·74
8·5	”	”	2·96	50	”	”	0.69
9	”	”	2·80	55	”	”	0·64
9·5	”	”	2·77	60	”	”	0·61
10	”	”	2·55	70	”	”	0·56
11	”	”	2·43	80	”	”	0·52
12	”	”	2·16	90	”	”	0·49
13	”	”	2·01	100	”	”	0·46

If, for example, 1 cubic centimetre of milk to 100 of water obscures the light, the percentage of fat is 23·43; if 8 cubic centimetres, added to 100 of

water, are needed to obscure the light, the percentage is 3·13, &c.; so that in four or five minutes an analysis of the milk is made, as far as the fat is concerned.

The advantage of this is obvious, both in detecting the removal of cream, and in seeing if milk is rich in butter.

(*e.*) Determine the amount of lactin by the saccharimeter, or by the copper solution. To do this, take 10 C.C. of milk, free it from casein and fat by warming, and the addition of a very small quantity of acetic acid; then add 90 C.C. of water. The whey being filtered, and the quantity known, put it into a burette, and drop it into a boiling solution of 10 C.C. of standard copper solution, diluted with water, until the fluid is colourless, *i.e.*, until the blue colour disappears, and yet no yellow is seen. Read off the amount of whey used and divide by 10; the result is the amount of milk which exactly decomposes 10 C.C. of the copper solution. The 10 C.C. of the copper solution equal to ·0666 grammes of lactin.* The amount of lactin in the 10 C.C. of milk is then known by a simple rule of three; and the amount in 100 C.C. of milk is at once obtained by shifting the decimal point one figure to the right.

Preparation of the copper solution.—Take 34·64 grammes of pure sulphate of copper, and dissolve in about 200 C.C. of water; dissolve in another vessel 173 grammes of tartrate of soda and potash, in 480 C.C. of caustic soda (or potash, if the caustic soda, as is probable, is not in the surgery); mix slowly, and dilute with distilled water to one litre.

1 C.C. = 0·005 grammes of glucose.
1 C.C. = 0·00666 grammes of lactin.

5. *Examine the milk microscopically.*—The only constituents of milk are the round oil globules of various sizes in an envelope and a little epithelium. The abnormal constituents are epithelium in large amount, pus, conglomerate masses, and casts of the lacteal tubules. The added ingredients may be starch grains, portions of seeds, and chalk (round and often highly refracting bodies, with often a marked double outline, and at once disappearing in acid). Colostrum, occurring for three to eight days after the birth of the calf, is composed of agglomerations of fat vesicles united by a granular matter. Infusoria are sometimes found in milk, and fungi (Oidium lactis and Penicillium) are almost invariably, if the milk has been kept.

Scheme for a Short Examination.

If milk is agitated with three or four volumes of carbon bisulphide, and then allowed to stand, the sulphide separates highly charged with an aromatic matter, which, on spontaneous evaporation, can be obtained as an unctuous imponderable residue, which possesses the aroma of the food of the animal (Millon).

As a medical officer is constantly called upon to examine milk, and will seldom have time to go thoroughly into all the points just noted, the following short scheme will be useful:—

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* In the two former editions of this book I stated the factor as ·08571. This was deduced from Rigaud's observations (Schlossberger's Lehrb. der org. Chem. 1860, p. 753), which gave the copper reducing power of glucose, as compared to lactin, as 12 to 7. But most later observations give the ratio as 10 to 7, or a little less. Poggiale's number is 10 C.C. of copper solution of the given strength = ·0667, and Hoppe-Seyler (Handb. der phys. und path. Chem. Anat. 1865, p. 358) gives the same factor. A number of experiments at Netley by Dr de Chaumont, which were controlled by the saccharimeter, gave as an average 10 C.C. = ·0666, and this number I have adopted. I also believe this number to be correct, as after many analyses I find the amount of lactin is always too great when the old factor is used.

1. Put some milk into the long glass for deposit, and for determining percentage of cream.

2. Take physical characters, reaction, and specific gravity.

3. Determine fat by Vogel's milk test.

The comparison of the specific gravity, and the amount of cream which rises, or of fat, will be found to give, in conjunction with the physical characters, a very good idea of the quality of the milk.

Sub-Section IV.—Preservation of Milk.

1. Boiled, the bottle quite filled, and at once corked up and well sealed, the milk lessens in bulk, and a vacuum is formed above. It will keep for some time. A little sugar aids the preservation. If the heat is carried in a close vessel to 250° Fahr., the milk is preserved for a very long time, even for years; the butter may separate, but this is of no consequence.

2. Sulphurous acid passed through it, or sulphite of soda added. This may be done after boiling.

3. A little carbonate of soda and sugar added, with or without boiling. This will keep for ten days or a fortnight.

In the market are—milk in tins, preserved in the usual way, by exclusion of air, concentrated milk mixed with sugar, and desiccated or dried milk. This last is milk carefully dried at a low temperature, with probably a little sugar. Dissolved well in water, it forms an excellent milk (see Concentrated Food, p. 249).

The preserved liquid milk* often has the butter separated; if so, it may be spread on bread. It is not easy to remix it with the milk, but it is said that the separation may be prevented by adding a little yolk of egg.

Sub-Section V.—Adulterations.

1. *Water.*—This is extremely common, and is, in fact, generally the only adulteration, best detected by specific gravity or evaporation.

2. Starch, dextrin, or gum, to conceal the thinness and the bluish colour produced by water. Not a common adulteration. Add iodine at once for starch; boil with a drop of acetic acid, and add iodine for dextrin, or add acetate of lead and then ammonia, a white precipitate falls.

3. Annatto or turmeric added to give colour. Liquor potassæ at once detects turmeric. By boiling the milk, the colouring matter remains in the serum.

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* A sample of French preserved milk, which I examined in 1862, was a good specimen of its class. It was in a glass bottle, well corked and sealed. The butter was separated, and consisted of 96 grains of fat and 4 of casein per cent. The liquid, without the butter, had a specific gravity of 1039. The milk had a pleasant taste, and was very feebly acid. In a few hours the acidity increased, and in forty-eight hours the casein had separated. The percentage composition was—

Casein,	4·140
Fat,	4·230
Lactin,	5·460
Salts,	·804
Water,	85·366
	100·000

This milk had apparently been preserved simply by boiling, and corking the bottle while the milk was hot. It had kept perfectly fresh for more than a year.

Liquid or semi-liquid milks are now sold, which are extremely good; they are dried at a very low heat, and then mixed with white sugar. I have examined four kinds, three of these being very similar; the fourth more watery, but of less cost. There was no impurity, and the casein, fat, and salts were in good proportion. The percentage of water was 20, 21·8, and 19·2 in the three concentrated milks, and 42·15 in the watery. After opening the tins all the samples remained good for almost a month.

4. Emulsions of seeds (hemp or almond), added; this is uncommon. Boil. The albumen of the seeds coagulates; the milk will not mix with tea. Hemp-seed gives an unpleasant odour to the milk (Normandy).

5. Chalk, to neutralise acid, and to give thickness and colour. Let it stand for deposit; collect and wash deposit, and add acetic acid and water; after effervescence filter, and test with oxalate of ammonia.

6. Carbonate of soda. Very difficult of detection unless the milk be alkaline. Determine the ash, and see if it effervesces; if so, either some carbonate has been added, or if the soda have united with lactic acid, this will be converted into carbonate, and enough lactic acid to give an effervescing ash does not exist in good milk.

7. Milk is often boiled to preserve it; it may then take up from the vessel lead, copper, or zinc, if these metals are used.

Cream is adulterated or made with carbonate of magnesia, tragacanth, and arrowroot. The microscope detects the latter, and particles of carbonate of magnesia (round) can also be seen and be found to disappear with a drop of acid.

Sub-Section VI.—Effects of Bad Milk.

Professor Mosler* has directed attention to the poisonous effects of "blue milk,"† that is to say, milk covered with a layer of blue substance, which is in fact a fungus, either the *Oidium lactis* or *penicillium*, which seems to have the power, in certain conditions, of causing the appearance in the milk of an aniline-like substance.‡ The existence of this form of fungus was noted by Fuchs as long ago as 1861. Milk of this kind gives rise to gastric irritation (first noted by Steinhof); and, in four cases noted by Mosler, it produced severe febrile gastritis.

Milk which is not blue, but which contains large quantities of Oidium, appears from Hessling's observations§ to produce many dyspeptic symptoms, and even cholera-like attacks, as well as possibly to give rise to some aphthous affections of the mouth in children.

SECTION XI.

BUTTER.

As an article of diet, butter supplies to most people the largest amount of fat which they take. Many persons take from 1½ to 2 oz. daily, if the butter used in cooking be included, and the average amount for persons in easy circumstances is 1 oz. daily. Butter appears to be easily digested by most persons, except when it is becoming rancid. It then causes dyspepsia and diarrhœa, and as a rule it may be said that decomposing fats of all kinds disagree.

Composition and Examination.

1. The average amount of water varies from 5 to 10 per cent. Hassall has found as much as 15½ per cent. in fresh, and 28½ per cent. in salt butter. The retail dealer, by beating up the butter in water endeavours to increase

* Virchow's Archiv, band xliii. p. 161 (1868).

† Blue milk is given by feeding cows with some vegetable substances, as *Myosotis palustris*, *Polygonum aviculare* and *Fagopyrum*, *Mercurialis perennis*, and other plants (Mosler); but this is different from the blue colour referred to above.

‡ Erdmann (Journal für Prakt. Chem., xcix. p. 385), quoted by Mosler, has discovered that vibriones have the power of producing aniline-colouring matter from protein substances.

§ Virchow's Archiv, band xxxv. p. 561. See also my Report on Hygiene, Army Medical Report, vol. vi. p. 385.

the amount. This can be detected by evaporation in a water bath; if the quantity of water be very large, melting the butter will show a little water below the oil.

2. *Casein.*—All butter contains some casein, as some milk is taken up with the cream. The best butter contains least. The amount can be told roughly by melting in a test-tube. The casein collecting at the bottom does not exceed one-third of the height of the contents of the tube in the best butter, or between one-third and one-half in fair butter. In bad butter it may reach to more than this. A better plan is dissolving the fat by ether, washing and then weighing the remainder; the casein then weighs from 5 to 3 grains in every 100 of very good butter. In bad butter it is much more than this.

The rancidity of butter is chiefly owing to changes in the fat, produced apparently by alterations in the casein, and therefore the greater amount of casein the more the chance of rancidity.

3. The fat amounts to from 86 to 92 per cent.; sometimes other fats—lard, beef, and mutton dripping—are used as adulterants. Butter oil consists of margaric, butyric, caproic, and other fatty acids, combined with glycerine. It is entirely soluble in ether at 65° (Horsley), and does not deposit. In this respect it differs from beef and mutton suet, which, if they dissolve, do so with greater difficulty, and deposit. The ether should be added gradually, and need not be measured. The fat begins to melt at 70° or 80°, and is entirely melted at about 120°. Beef dripping begins to melt at 90° to 100°, and is entirely melted at 120° to 130°. Mutton dripping commences to melt at about 100°, and is entirely melted at about 150°.

The melting-point of butter fat is then slightly below that of beef, and a good deal below that of mutton dripping, and this test, taken in connection with the ether test, may be useful.

The best way of taking the temperature is to put a *small* quantity of butter into a test-tube; immerse it well in water, and heat the water gradually, observing its temperature by a thermometer.

The taste of butter fat when melted, separated from the casein, and allowed to cool, is very characteristic; while that of mutton fat is also distinguishable.

Hassall has pointed out that butter under the microscope presents only oil globules, while lard contains numerous crystals of margaric and stearic acids. If any membrane is mixed with the butter, it is at once detected by the microscope.

4. Salt is added to all butter; in fresh butter it should not be more than ·5 to 2 per cent., and in the salt butter it should not exceed 8 per cent. To determine the amount of salt, wash a weighed quantity of butter thoroughly with distilled water, and determine the chloride of sodium by the standard solution of nitrate of silver.

5. Potato or other starch is sometimes added. It is a rare adulteration, and at once detected by iodine, either used at once or after melting. Gypsum and sulphate of baryta have, it is said, been added. This must be rare, and would be at once detected by melting and pouring everything off the insoluble powder, or by incinerating.

Scheme for a Short Examination.

1. Determine quality by the taste of the whole butter,—by the taste of the melted and recongealed fat,—and by the smell.
2. Melt in a tube for the approximate amount of casein.
3. If necessary determine melting-point and solubility in ether.
4. Examine with microscope for animal membranes, crystals or stearine, or starch globules, and if necessary, test with iodine under microscope.

Preservation of Butter.—Pouring water which has been boiled over butter will keep it for some time; but a better plan is one discovered by M. Bréon,* viz., water acidulated slightly (3 grammes to 1 litre) with acetic or tartaric acid, is added, and the whole is placed in a close-fitting vessel. Sugar also has a preventative effect, especially when mixed with a little salt.

SECTION XII.

CHEESE.

As an Article of Diet.—It contains a very large amount of nitrogenous matter in small bulk (page 165), and as it is agreeable to the palate, it must be an excellent food for soldiers in war. About ½ ℔ contains as much nitrogenous substance as 1 ℔ of meat, and ⅓ of a ℔ as much fat. It does not, however, keep well in warm climates.

The quality is known by the taste. The only adulteration is from substances to give weight. Starch is chiefly employed, and can be detected at once by iodine. There is usually about 5 or 6 per cent. of salt.

Sulphate of copper and arsenious acid are sometimes used to destroy insects; the rind is then the most poisonous part. Copper is detected by ammonia or potassium ferrocyanide. Arsenic by any test (Reinsch's or Marsh's).

The *Acarus domesticus*, *Aspergillus glaucus* (blue and green mould), and *Sporendomema casei* (red mould), form during decay. During decay the fat augments at the expense of the casein; leucin is produced, and baldrianic and butyric acids. Lactic acid is also often produced by the lactin of the milk contained in the cheese. The aroma of cheese partly arises from this decomposition, and the production of volatile acids.

SECTION XIII.

EGGS.

It is needless to say anything of eggs as an article of diet; they contain albumen and fat in very digestible forms.

Composition and Choice.—An egg weighs from 600 to 950 grains, or even more; the average weight is about two ounces avoir.; 10 parts are shell, 60 white, and 30 yolk; the white contains 86 per cent. of water; the yolk 52 per cent.; 100 grains of egg, therefore, contain—

10	grains	shell.
22·8	,,	albumen and fat.
67·2	,,	water.
100·0		

If an egg weighs 2 ounces, it contains nearly 200 grains of solids; this is a convenient number to remember, as 100 grains correspond to 1 ounce.

For choice, look through the egg; fresh eggs are more transparent in the centre, old ones at the top. Dissolve 1 ounce of salt in 10 ounces of water; good eggs sink; indifferent swim. Bad eggs will float even in pure water.

A little instrument has been lately proposed by Mr Schæfer, which may be useful. Two pieces of mirrored glass at an angle of 45°, and fixed in a box which has a round hole at the top, and another at one side; the egg is placed in the top hole, and light (sun light or strong reflected light) being thrown through it, the image is seen in the mirror; if the egg be fresh, it is almost transparent, but becomes dark when getting stale.

* Payen. Des Subst. Alim. 4th ed. p. 179.

Preservation.—Eggs are packed in sawdust or salt, or are covered with gum or oil, or placed in lime-water, with a little cream of tartar.* Boiling for half a minute also keeps them for some time; in fact, anything which excludes air.

The lime-water gives them, it is said, a peculiar taste, and makes the albumen more fluid.

SECTION XIV.

SUGAR AND STARCHES.†

Sub-Section I.—Sugar.

Choice and Examination.—The sugar should be more or less white, crystalline, not evidently moist to the touch, and should dissolve entirely in water, or leave merely small fragments, which on examination with the microscope will be found to be bits of cane. The whiter the quality the less is the percentage of water, which varies in different kinds of sugar, from about ·25 per cent. (in the finest sugars), to 9 or even 10 per cent. (in the coarse brown sugars).

The unpurified sugars contain albuminous matters which decompose, and a sort of fermentation occurs. The Acarus, or sugar-mite, is usually found in such sugar, which is not known to be hurtful. Fungi also are very frequently present.

Method of Examination.

1. Determine physical characters of colour, amount of crystallisation, &c.
2. Dissolve in cold water; fragments of cane, starch, sand, gypsum, phosphate of lime are left behind; test with iodine for starch. The best way is to dissolve under the microscope, as all adulterations are at once detected.
3. Determine percentage of water by drying thoroughly 100 grains, and again weighing.
4. Excess of glucose (a little is always present) is detected by the large immediate action on the copper solution.

Sub-Section II.—Arrowroots.

Maranta Arrowroot (West Indian).—The chief kind is obtained from the *Maranta arundinacea.* The quality of Maranta arrowroot is judged of by whiteness; by the grains being aggregated into little lumps, and by the jelly being readily made, and being firm, colourless, transparent, and good tasted. The jelly remains firm for three or four days without turning thin or sour, whereas potato flour jelly in twelve hours becomes thin and acescent. Under the microscope the starch-grains are easily identified. They are slightly ovoid, like potato starch, but have a mark or line at the larger end (the hilum of the potato starch is at the smaller end), the concentric lines are well marked. The most common adulterations are sago, tapioca, and potato starch. All these starch-grains are readily detected.

Curcuma Arrowroot.—Arrowroot obtained from the Curcuma has the same physical characters as Maranta, but under the microscope the starch-grains are large and oblong, marked with very distinct concentric lines, which, however, are not entire circles, having an indistinct hilum at the smaller end.

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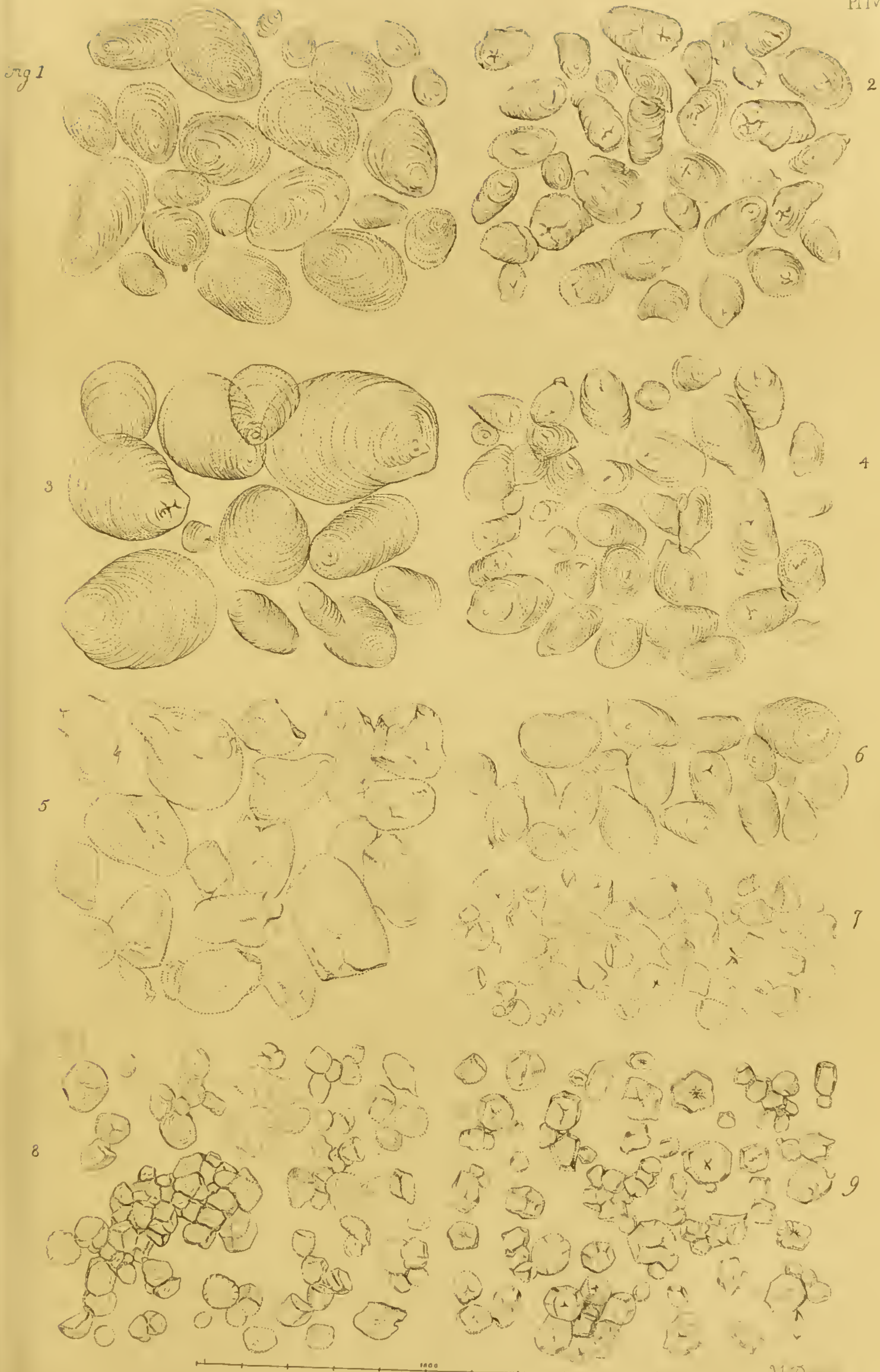
* It is said that covering them with a solution of bees-wax in warm olive oil (⅓d of bees-wax, ⅔ds of olive oil) will keep them for two years.—*Chemical News*, August 1865, p. 84.

† A plate of drawings of some starches by Dr Maddox is given further on, in addition to the woodcuts.



1. Potato - Starch
2. Bermuda Arrowroot
3. Tous les Mois
4. St Vincent Arrowroot
5. Sago of Commerce
6. Port Natal Arrowroot
7. Rio Arrowroot
8. Tapioca
9. Maize

Manihot Arrowroot.—This is obtained from Rio. The starch-grains are very marked. (See Plate of Starches).

Tacca or Otaheiti Arrowroot.—I have never seen this arrowroot, but Hassall gives a figure which shows that the starch-grains resemble those of the Manihot.

Arum Arrowroot.—The Arum or Portland arrowroot has small, angular, and facetted starch-grains, which cannot be confounded with any of the former. They are a little like maize. This is sometimes called Portland Sago.

Fig. 60.—West Indian Arrowroot (*Maranta arundinacea.*) Scale 1-1000 of an inch.

British or Potato Arrowroot.—Under the term "Farina," potato starch is sold in the market; so white and crackling, and making so good a jelly, that it is not always easy to distinguish it from Manihot. The microscope at once detects it (see page 209). The pear-shaped grains, marked hilum towards the smaller end, and the swelling with weak liquor potassæ, render a mistake impossible. In making the jelly a much larger quantity is required than of the Maranta arrowroot.

Canna or Tous les Mois *Arrowroot.*—The starch-grains are like those of the potato, but much larger, and the concentric lines are beautifully marked and distinct. (See Plate of Starches).

SUB-SECTION III.—TAPIOCA.

This is obtained from the finest part of the pith of *Jatropha manihot* or *Cassava.*

Under the microscope the starch-grains are small, with a central hilum; and sometimes three or four adhere together and form compound grains.

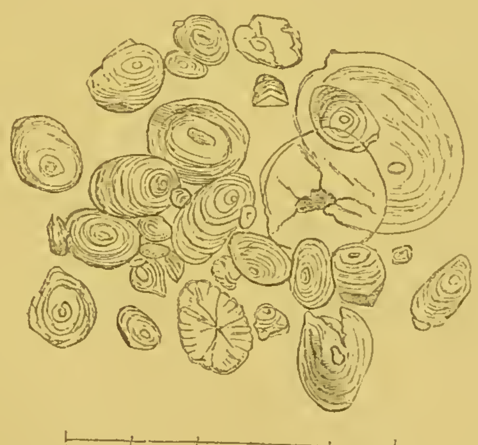


Fig. 61. -Tapioca. Scale 1-1000th of an inch.

It is adulterated with sago and potato starch, both of which are easily detected by the microscope. (See Plate of Starches.)

Sub-Section IV.—Sago.

The best kinds are derived from the sago palm (*Sagus farinifera*), but the sago of the *Cycas circinalis* is also sold; it is, however, inferior.

Granulated sago is either "common" or "pearl;" the latter is chiefly used in hospitals. The starch is soluble in cold as well as in hot water. The starch-grains are elongated, rounded at the larger end, and compressed at the other; and hence their shape is quite different from the potato starch. The hilum is a point, or more often a cross, slit, or star, and is seated at the smaller end; whereas, as in the Maranta arrowroot, the hilum is at the larger end. Rings are more or less clearly seen.

In the market is a factitious sago made of potato flour. This is sometimes coloured red or brownish, either from cochineal or sugar. In thirty specimens Hassall found five to be fictitious. The microscope easily detects potato starch.

SECTION XV.

CONCENTRATED AND PRESERVED FOOD.*

For the military surgeon this subject is so important, that it is desirable to put the chief facts under a separate section.

It is obvious how important it must be in time of war to have a food which may be at once nutritious, portable, easily cooked, and not liable to deterioration. Lind's sagacious mind long ago saw this, and he strongly urged the advisability of having on board ship prepared food of this kind. It must be remembered, however, that a man must get his 260 to 300, or even 350 grains of nitrogen, and 8 to 12 ounces of carbon, in each twenty-four hours, besides some hydrogen and salts. The work of the body when in activity cannot be carried on with less; and at present these elements cannot be presented to us in a digestible form in a smaller bulk than 22 or 23 water-free ounces. Concentration at present cannot be carried beyond this, and practically has not really been carried to this point. Life, however, and vigour may for some days be preserved with a much less amount; and I have reduced the total amount of food to 11 water-free ounces daily, with full retention of strength for seven days, though the body was constantly losing weight. For expeditions of three or four days, if transport were a matter of great difficulty, soldiers might be kept on 10 or 12 ounces of water-free food daily, provided they had been fully fed beforehand, and subsequently had time and food to make up the tissues of their own body, which would be expended in the time, and would not have been replaced by the insufficient food.

When we inquire into the concentrated foods now in the market, some of which profess to supply all the substances necessary for nutrition, we find them not very satisfactory. They are often not so concentrated as they might be, or are deficient in important principles, or are disagreeable to the taste.

Dried Meats.—Meat dried at a very low heat has been brought into the market by Verdeil. It has lost the greater part of its water, is hard, and requires very careful cooking, but is believed to be nutritious when well prepared.

Messrs M'Call of London have also prepared an excellent dry meat; it is sold in packets, each of which weighs 4 oz., and is intended for one meal. It contains salt and pepper, and 12 per cent. of water.

* Dr Letheby informs us, that from 1800 to 1855 there were 177 patents taken out for drying and preserving food. Of these, 26 were for drying the food, 31 for excluding atmospheric air, and 8 for giving an impervious coating.

Hassall's Flour of Meat.—Good fresh meat, freed from visible fat, is carefully dried at a very low temperature, and is pulverised by machinery, so that a very fine smooth powder is formed. This is mixed with about 8 per cent. of arrowroot, $2\frac{1}{2}$ per cent. of sugar, and 3 per cent. of a mixture of salts, pepper, spices, and colouring matter. The object of the arrowroot is to assist its suspension in water. From an analysis of 3 samples of the commercial flour of meat, I found the average to be in 100 parts—water, 12·68; fat, 10·99; salts, 3·82; and nitrogen, 8·81 (= nitrogenous compounds, 55·5); the rest is made up of arrowroot, spices, sugar, &c. The free acidity, taken as lactic acid, is 1·8 per cent. As this flour of meal contains albumen and fibrine in a condition well adapted for nutrition, it is probably more suited than Liebig's extract for a diet of long continuance. I have tried some experiments with it, and found that, when given with bread alone, it did not nourish properly. Two gentlemen, who lived on it and bread for some days, both became indisposed, and there was great dyspepsia, evidently imperfect digestion, with, in both cases, an eruption of acne. When to the same diet a larger amount of fatty and vegetable foods were added, without any increase in the meat or bread, the effect on health was described by both observers as perfectly marvellous; all symptoms of illness disappeared, and with this proper admixture of foods, Hassall's flour of meat answered admirably.* Hassall's flour of meat keeps very well; but if the open tins are exposed to the air, after several months it slightly changes colour, and then acquires a peculiar odour. Subsequently it decomposes. But if well fastened, it will keep for a very long time. It will certainly be a valuable addition to the resources of the military surgeon.

Under the terms *Tasajos* and *Charqui*, two kinds of meat are prepared in South America; it is probable that these terms have not always been used in the same sense. According to Mr Bridges Adams, Tasajos is meat cut in thin slices, dipped in brine, and then partially dried. Charqui is thin strips of muscular fibre from which the fat is removed, dried rapidly by sun heat, and sprinkled with maize. The salted dried meat (Tasajos), analysed by Hassall, gave from 29 to 59 per cent. of water; 15 to 41 per cent. of nitrogenous substances; 3 to 12 of fat, and 11 to 20 of salts.

The dried meat of the Kaffirs (beltong) is very much the same; great hunks of beef are sun-dried, and remain undecomposed for a long time. So also in Egypt the meat is dried by exposure to the sun and north wind.

The Pemmican of the arctic voyagers is a mixture of the best beef and fat dried together, and is an excellent food, though rather expensive.

Liebig's *Extractum Carnis* is the juice of meat extracted on the following plan:—Every particle of meat is separated from fats and tendons, and is then subjected for some time to a moderate heat; a viscid dark extract at last collects, which contains the salts, creatin, and other organic nitrogenous substances. Mixed with warm water, this extract gives a highly agreeable and nutritious beef-tea or mutton broth. One ℔ of mutton gives about 2-5ths of an ounce of extract. It has the remarkable property of not decomposing; Liebig has had some for fifteen years in a bottle loosely stoppered.

There are now numerous samples of *Extractum Carnis* in the market, prepared in South America and Australia. The majority have an almost identical composition. I have analysed five different kinds, and there are other analyses

* I have seldom been more impressed than with these experiments; the evident difficulty in digestion of Hassall's food by itself, and its perfect digestibility and evident nutritive power when there was admixture of vegetables and carbo-hydrates and fat, convinced me of the immense importance of attending to these points in cases of sickness. I feel sure that in many cases, by adhering too closely to one class of diet, we must do injury.

by Apjohn and Hassall. Two of my five samples were obtained from the Fray Bentos Company, the others from Australia, Buenos Ayres, and Monte Video. The average amount of water (using round numbers), was 16 per cent.; of ash, 20 per cent.; of nitrogen, 8 per cent.; the lowest being 6·6, and the highest 10·14. All had an agreeable acidity; the average quantity was equal to 7 grains of free lactic acid (assuming that acid to be the sole cause of the acidity, which is not certain), and in addition there was combined lactic acid equal to 5½ grains. In all these respects the several extracts were very similar. There are some other extracts in the market, which are less rich in salts and more watery, but containing almost as much nitrogen; gelatine appears to have been added to these.

When Liebig's extract is taken during fatigue, it is found to be remarkably restorative, increasing the power of the heart, and removing the sense of fatigue following great exertion. Mixed with wine, it has been employed with great success in rousing men in collapse from wounds. Its restorative effects may partly be attributable to its large amount of salts and potash, which at once are taken by the muscles, but possibly also from its nitrogen, and from the ease with which, from its digestible form, it is absorbed and used. As, however, the nitrogenous compounds in the *Extractum* are not in the form of albumen or fibrine, but of other compounds (creatine, extractives soluble in water, and alcohol), it has been supposed that the nitrogen would not be capable of being employed in the nutrition of muscles or gland-cells, and, in fact, that the *Extractum Carnis* does not represent a true nutritive albuminate. On such a point as this experimental evidence can alone decide. I kept two friends on Liebig's food and bread for some time; one did well, the other was evidently not properly nourished, and, in fact, there seemed to be some impairment and delay of nutrition; but this was partly, if not altogether, owing to the want of starchy and saccharine food, for the same effects were produced when Hassall's food was given in the same way, *i.e.*, without proper admixture of the carbo-hydrates and fats. Sick persons have been fed, and apparently well fed, with Liebig's essence in place of meat. The point is of importance to military surgeons, who may have to rely on the *Extractum Carnis* during war for the supply of nitrogen, and it is very desirable it should be experimentally settled.

That the potash salts in small quantity have a powerful stimulating action on the muscles is generally admitted, but it has been supposed that when in large quantity they have the reverse effect; and some experiments by Kemmerich* have been cited as showing that the *Extractum Carnis* may in this way do harm. Although Kemmerich's experiments (as has been pointed out by Baron Liebig) do not bear the interpretation that has been put on them, there can be little doubt that, like a great excess of meat (which, according to Ranke, has the same effect from the excess of potash salts), the extract may be injurious if given in very great quantities; but this is never likely to be the case. An acquaintance with its composition, and a little calculation of the amount of potash in the quantity given, would be sufficient safeguard. There are 20 grains of salts on an average in 100 grains of extract; 17 of these are soluble salts, of which potash salts will make 90 per cent.; there would thus be about 15 grains of potash salts, or in an ounce about 66 grains. A man could surely take half an ounce to an ounce daily without

* An account of these experiments, which were conducted on rabbits, is given in the Archiv fürges. Phys. 1868, p. 120. The stimulating effect is well marked in the circulation of rabbits; but when the decoction of 2 to 3 lb of meat was evaporated to 1¼ or 2 fluid ounces (and this amount was given to a rabbit) is produced cardiac paralysis. The same effect was produced by incinerating the evaporated broth, dissolving the salts, and using them instead of the broth.

injury. The great amount of lactic acid must be an important ingredient. Although the free acidity is doubtless partly owing to acid phosphate, some of it must be caused by lactic acid; and there is a large amount of an acid combined with potash which is destroyed by incineration, and can hardly be anything but lactic acid. It seems probable, though actual proof has not yet been given, that the *Extractum Carnis* may be an anti-scorbutic of some power.

The "concentrated beef-tea" is beef-tea and the juices of the compressed beef mixed and evaporated. This is a highly nutritious substance, and most useful to the army surgeon. Mixed with wine, and given as soon as possible after wounds are received, in the time of shock and collapse, it was found in the Austrian army (in 1859) to save the lives of many wounded men, and the experience of the Federal American army is to the same effect (Hammond).

*Bellat's Extract of Meat.**—In making this extract, the meat deprived of fat and tendons is cut up very fine, and exhausted with cold water; the residue is vapour heated in hermetically-sealed vessels, and is thus heated with its own weight of water and a proper quantity of bone to 194° Fahr. for six hours; it is subsequently pressed in an hydraulic press, mixed with water and cooked vegetables. To this mixture the cold-water extract is then added, and the whole is heated to clarify it, and is then filtered. It is subsequently evaporated to the consistence of thick honey, and packed in metal boxes, from which the air is excluded. A little less than an ounce (25 grammes) in 1¾ pint (1 litre) of water makes a good beef-tea.

Meat Biscuits.—These biscuits, or powders, for they are generally powdered and sold in canisters, are formed by mixing rich extract of meat with wheat flour, and drying. The biscuit of Mr Gail Borden, of Galveston, in Texas, contains equal parts of meat-extract and flour dried (made in a Papin's digester). A biscuit like this has been very much used in the American war. The inventor represents that 10 ℔ will last a man for fourteen days, or at the rate of 11·2 ounces a-day, but this is clearly an exaggeration. The biscuit, after being powdered, is soaked in cold water for a few minutes, then boiled from twenty to thirty minutes.

French Meat Biscuit.—This is similar, except that dried vegetables are added. The "biscuit-viande" of Callamond contains—

Dry flour,	76·45	per cent.
,, meat,	5·79	,,
Fat,	6·27	,,
Dried meat,	2·77	,,
Spices and sugar,	·92	,,
Water,	7·8	,,
	100·00	,,

The taste is not agreeable.

Another French meat biscuit is prepared by M. de Beurmann, and obtained a medal at the Exhibition of 1851. Its composition is probably similar.

Meat biscuits can be made in a very simple way, by mixing together, cooking, and baking 1 ℔ flour, 1 ℔ meat, ¼ ℔ fat (suet), ½ ℔ potatoes, with a little sugar, onion, salt, pepper, and spices. A palatable meat biscuit, weighing about 1¼ ℔, containing 10 to 12 per cent. of water, is then obtained, which keeps quite unchanged for four months.

Blood Biscuit.—A patent was taken out some years ago (1855) by M. Rohrig, which aimed at preparing a biscuit with dried blood, mixed with

* Poggiale, Rec. de Mem. de Med. Milit. 1868, Avril, p. 257.

boiled rice, and potato and wheat flour. This does not appear to have ever come into use.

*Carniset.**—Under this title Messrs Gehrig and Grunzig, of Berlin, have made a food, which is sold under the form of little millet-like grains, and is flavoured in two or three ways. The composition of the most nutritious kind is—

Nitrogenous substances,	35·28	per cent.
Fatty ,,	4·25	,,
Starchy, ,,	34·68	,,
Salts,	8·8	,,
Water,	16·99	,,

It is cooked very rapidly, but is not palatable. It is used with bread; and 8 ounces daily, with 10 ounces of bread, making a total amount of water-free solids of about 12½ ounces avoir., maintains the strength and vigour for six or eight days fairly, but the body loses weight. It appears to be a meat-extract mixed with the flour of a cereal, either wheat or barley. It is deficient in fat and salts.

Rata Française au Gras.—Small cakes, of a very strongly flavoured meat, mixed with salt and flour, are sold under this term in Paris. 15 grammes (= 231 grains) are mixed with 1½ pint of water, and make a soup, which, when mixed with vegetables, is not unpalatable. The Prussian army, in 1861, was fed for a fortnight on pea-soup flavoured with Rata; a little bacon and salt were added, and the men were kept in good health. It contains about 5 per cent. of nitrogenous substance, so that the supply of nitrogen in this form is very small.

Dried Cerealia.—Many flours, if well dried, will keep for a long time. Hard's "farinaceous food for infants" is wheat flour baked. Densham's "farinaceous food" is composed of 3 parts wheat flour and 1 part of barley, dried at a heat of 200° Fahr. It loses from 25 to 30 per cent. in weight. The Russian Government formerly used a cake composed of a mixture of oatmeal and malt (2 parts to 1); it was baked, and formed an agreeable article of food. When placed in water in a warm place, a slight fermentation goes on, and a kind of beer is produced. I have kept these cakes unaltered for more than a year. There are now in the market different kinds of malt biscuit and granulated malt food. Liebig's food for infants is composed of equal parts of wheaten flour and malt flour mixed with a little carbonate of potash and cooked with 10 parts of milk. The wheat and malt flour are now usually cooked first, and sold in powder ready to be cooked again with the milk. Some kinds of the nutritive red and dark coloured rice made into cakes and dried are used by the Burmese soldiers on long marches, and a man will carry, it is said, enough food for ten or twelve days.

Dried Bread.—In addition to biscuit already described, bread has been partially dried by being pressed in a hydraulic press (method of Laignel). Much water flows out, but when taken out the bread still feels moist. In a day or two, however, it becomes as hard as a stone, and in a year's time will be found good and agreeable. Placed in water, it slowly swells. The "pain biscuité" of the French army is bread dried by heat (see Bread).

Dried Potatoes are sold in two forms—slices and granulated. In either case the potato is easily cooked, and is very palatable. It should be soaked in cold water first for some time, then slowly boiled, or, what is much better, steamed.

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* See a paper on this food by the Professors of the Army Medical School.—*Army Medical Report* for 1861, p. 386.

Dried Vegetables (other than Potatoes).—Dried and compressed vegetables of all kinds (peas, cauliflowers, carrots, &c.) are now prepared, especially by Messrs Masson & Chollet, so perfectly, that if properly cooked they furnish a dish almost equal to fresh vegetables. They must be soaked for some time (four to six hours) in pure water, and then cooked very slowly. If there is any disagreeable taste from commencing putrefaction, which is very rare, a little chloride of lime removes it at once. Potassium permanganate can be also used for this purpose.

As anti-scorbutics they are said to be inferior to the fresh vegetable (experience of American war), but are still much better than nothing.

Dried Milk.—Preserved milk is sold in a liquid form (see Milk), but is also sold as a powder. Desiccated milk is now very well prepared; I examined a sample of Fadeuille's desiccated milk; the bottle contained 1502 grains, consisting of—

Casein,	524·588
Fat,	330·442
Lactin,	492·265
Salts,	73·898

and intended to be mixed with a quart of water. When so mixed it had a specific gravity of 1026; a little sugar had probably been added. Cream to the extent of $\frac{3.5}{100}$ths rose to the surface. The milk turned acid in twenty-four hours.

Dried Eggs.—The yolk is not easily kept after drying, but the white can be so; it is cut into thin scales, and 44 eggs make about 1 ℔. The yolk and white are also mixed with flour, ground rice, &c., and are then dried.

For the soldier, on active service, who is compelled to use these concentrated foods, the following articles seem most suitable:—For meats, M'Call's cylinders, Hassall's flour, and Liebig's extract and meat-biscuits, would give the necessary animal diet. Biscuit, common malt, dried bread, wheat flour, oatmeal, and rice, would be the best transportable cereal foods. Peas and beans in lesser quantity, and dried potatoes, and other dried vegetables, would complete the articles of necessary diet; while for hospitals, preserved milk and dried eggs should be added. An army could carry in the field sufficient of such dried provisions, with small transport, to maintain it in the enforced absences of fresh meat, bread, and vegetables; and if a besieged fortress were properly stored with such food, it would never be driven to surrender by famine, if, in addition, there was a sufficient store of lemon-juice.

In the use of these concentrated foods there are one or two points which should be explained to soldiers. The bulk is so comparatively small that men will eat rapidly two or three days' allowance. It should be explained to them that the feeling of hunger will be removed by the smaller bulk if they will allow time for this. There is, however, often a sort of hunger felt even after eating slowly, on account of the small bulk and the easy digestion of these well-cooked substances. The best way to obviate this is to make them into thick soups, if time and means permit, so as to form a greater bulk. This has the advantage also of giving the soldier warm food, a point of the very greatest importance; for it is certain that under fatigue, and during cold, nothing is more reviving than warm food.

CHAPTER VII.

BEVERAGES AND CONDIMENTS.

SECTION I.

ALCOHOLIC BEVERAGES.

ALTHOUGH it is convenient to place all the beverages which contain Alcohol under one heading, they yet differ materially in composition and effects. The medical officer has to deal with only a few of these liquids.

SUB-SECTION I.—BEER.

Composition.—The law allows only malt and hops to be used in brewing; and beer consists of malt and hop extracts; of alcohol, formed by fermentation; and of salts added in the water, or present in the malt and hops.

The specific gravity varies from 1006 to 1030, or even more, in the thick German beers; the average in English beers and porters is from 1010 to 1014. The percentage of malt extract (dextrin, cellulose, sugar) is from 4 to 15 per cent. in ale, and from 4 to 9 per cent. in porter. It is least in the bitter, and highest in the sweet ales. The hop extract (lupulit and resin) is in much smaller amount. The alcohol varies from 1 to 10 per cent. in volume. The free acidity which arises from lactic, acetic, gallic, and malic acids, ranges (if reckoned as dry acetic acid) from 15 to 40 grains per pint. The sugar has a great tendency to form glucinic acid ($C_8H_5O_5$). There is a small quantity of albuminous matter in most beers, but not averaging more than ·5 per cent. The salts average ·1 to ·2 per cent., and consist of alkaline chlorides, and phosphates, and some earthy phosphates. There is a small amount of ammoniacal salt. The dark beers, or porters, contain caramel and assamar. Free carbonic acid is always more or less present; the average is ·1 to ·2 parts by weight per cent., or about $1\frac{3}{4}$ cubic inch per ounce. Volatile and essential oils are also present.

Adopting mean numbers 1, pint (20 ounces) of beer will contain:—

Alcohol, ...	1 ounce.
Extractives, dextrin, sugar, . . .	1·2 ,, (524 grains).
Free acid, ...	25 grains.
Salts, ...	13 grains.

As an article of Diet.—There appear to be four ingredients of importance —viz., the extractive matters and sugar, the bitter matters, the free acids, and the alcohol. The first, no doubt, are carbo-hydrates, and play the same part in the system as starch and sugar, appropriating the oxygen, and saving fat and albuminates from destruction. Hence, one cause of the tendency of persons who drink much beer to get fat. The bitter matters are supposed to be stomachic and tonic; though it may be questioned whether we have not gone too far in this direction, as many of the highest-priced beers contain now little

else than alcohol and bitter extract. The action of the free acids is not known; but their amount is not inconsiderable; and they are mostly of the kind which form carbonates in the system, and which seem to play so useful a part. The salts, especially potassium and magnesium phosphates, are in large amount. To the action of alcohol, reference will be presently made.

It is evident that in beer we have a beverage which can answer several purposes—viz., can give a supply of carbo-hydrates, of acid, of important salts, and of a bitter tonic (if such be needed), independent of its alcohol.

In moderation, it is no doubt well adapted to aid digestion, and to lessen to some extent elimination of fat. It may be inferred that beer will cause an increase of weight of the body, by increasing the amount of food taken in, and by slightly lessening metamorphosis; and general experience confirms those inferences.

Physiological Action.—The action on tissue metamorphosis, as far as is known, is one of lessened excretion; the urea and pulmonary carbonic acid being both decreased. On the nervous system, the action is probably the same as that of alcohol. The peculiar exhausting or depressing action of beer taken in large amount has been ascribed by Ranke * to the large amount of potash salts, but probably the other constituents (especially the hop) are also concerned.

When beer is taken in daily excess, it produces gradually a state of fulness and plethora of the system, which probably arises from a continual, though slight interference with elimination, both of fat and nitrogenous tissues. When this reaches a certain point, appetite lessens, and the formative power of the body is impaired. The imperfect oxidation leads to excess of partially oxidised products, such as oxalic and uric acids. Hence many of the anomalous affections, classed as gouty and bilious disorders, which are evidently connected with defects in the regressive metamorphosis.

The question, what is excess? is not easy to answer, and will depend both on the composition of the beer, and on the habits of life of those who take it.

EXAMINATION OF BEER.

This is directed to ascertain—1. Quality; 2. Adulterations.

1. *Quality.*

1. *Physical Characters.*—The beer should be transparent, not turbid. Turbidity arises from imperfect brewing or clarifying, or from commencing changes. If the latter, the acidity will probably be found to be increased. The amount of carbonic acid disengaged should neither be excessive nor deficient.

The taste should be pleasant. If bitter, the bitterness should not be persistent. It should not taste too acid.

Smell gives no indication till the changes have gone to some extent.

2. *Determine specify Gravity.*—If this is done after the alcohol is driven off (see Determination of Alcohol), an approximate conclusion can be formed of the amount of solids. The more malt extract, the greater is the *body* of the beer.

Specific Gravity after loss of Alcohol.	Per cent. of Extract.	Specific Gravity after loss of Alcohol.	Per cent. of Extract.
1004	1	1024	6
1008	2	1028·1	7
1012	3	1032·2	8
1016	4	1036·3	9
1020	5	1040·4	10

* Phys. des Menschen, 1868, p. 139.

3. *Determine Acidity.*—This is a very important matter, as the increase of acidity is an early effect when beer is undergoing changes.

The acidity of beer consists of two kinds.

Volatile Acids—viz., acetic and carbonic.

Non-Volatile Acids—viz., lactic, gallic or tannic, malic, and sulphuric, if it has been added as an adulteration.

To determine acidity of beer and all other liquids, the easiest plan is to prepare an alkaline solution of known strength.

Standard Alkaline Solution.

A standard acid is first made, and crystallised oxalic acid ($C_2H_2O_4 \cdot 2OH_2$) (equivalent 126,) is now usually employed.

Half an equivalent (63 grammes or grains) is taken and dissolved in 1 litre of water.

A convenient amount for beer, wine, vinegar, or lemon-juce is, 6·3 grammes, in 1000 C.C. of water. 1 C.C. of this solution contains therefore ·0063 grammes of crystallised oxalic acid, and is exactly equal, of course, to an equivalent proportion of any other acid.

A solution of liquor potassæ, or sodæ, is now taken and graduated with the acid solution; so that 1 C.C. of oxalic acid solution shall exactly neutralise 1 C.C. of the alkaline solution. Then 1 C.C. of the alkaline solution will be equal to ·0063 grammes of oxalic acid, or to an equivalent proportion of any other acid, as shown in the table.

1 C.C. alkaline solution equals	·0063	grammes of	crystallised oxalic acid ($C_2H_2O_4 + 2OH_2$)
"	·0051	"	acetic anhydride or anhydrous acetic acid ($C_4H_6O_3$).
"	·0060	"	glacial acetic acid ($C_2H_4O_2$).
"	·0192	"	citric acid ($C_6H_8O_7$).
"	·0150	"	tartaric acid ($C_4H_6O_6$).
"	·0090	"	lactic acid ($C_3H_6O_3$).
"	·0040	"	sulphuric anhydride or sulphuric trioxide (SO_3).
"	·0049	"	sulphuric acid (SO_4H_2).*

In preparing the alkaline solution, dilute the common liquor potassæ of the pharmacopœia with about 7 or 8 parts of water; put a portion into the burette, and add it to 10 C.C. of the standard acid, coloured with litmus. It will be found that about 8 or 9 C.C. of the liquor potassæ will neutralise the 10 C.C. of acid; read off the amount of alkaline solution used, measure the remaining portion, and calculate by rule of three how much water must be added to dilute it, so that 10 C.C. shall be required to neutralise 10 C.C. of the acid.

Example.—10 C.C of acid required 8·17 C.C. of alkaline solution, and the remainder of the alkaline solution measured 160 C.C.

$$8{\cdot}7 : 10 : : 160 : x$$
$$x = 183{\cdot}9.$$

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* In stating the result of the inquiry, the composition of the acids should always be given, by adding the symbols, otherwise error may arise. If the symbols are given, no mistake is possible. It must be remembered that in this edition the atomic weights are those of the unitary system. With regard to litmus, it ought to be very good and neutral. The best way of making it, is to make first a concentrated watery solution, then to add dilute sulphuric acid to slight acid reaction, boil, and then add liq. baryta to very slight alkaline reaction; destroy the alkaline reaction by passing through two or three bubbles of carbonic acid. Boil, filter, and add one-tenth part of alcohol.

Thus (183·9 – 160 =) 23·9 C.C. of water must be added to the 160 C.C., to dilute it to the proper strength. Add then this amount of water, and test it once more to see that there is no mistake. The alkaline solution does not keep well, and must be re-tested, if a long time passes without its being used.

Having prepared the alkaline solution, take a measured quantity of beer (say 10 C.C.), and drop in the alkaline solution from the burette, till exact neutrality is reached. Then read off the numbers of C.C. of alkaline solution used; multiply by the co-efficient of anhydrous acetic acid, and the result will be the amount of total acidity in the quantity of beer operated on, as expressed by anhydrous acetic acid (the symbols being always used in the report). By shifting the decimal point two places to the right, the amount per litre is given. To bring grammes per litre into grains per ounce, multiply by 70, and divide by 160; or, what is the same thing, multiply at once by ·437. If an ounce has been taken instead of 10 C.C., multiply the grammes by 15·43 to bring the amount into grains.

If the alkaline solution cannot be made, dried carbonate of soda must be used; weigh 53 grains, and dissolve in 1000 C.C.; 1 C.C. = ·053 grains, and this is equivalent to ·063 grains of crystallised oxalic acid. If there is no burette, then weigh 100 grains of carbonate of soda; add portions gradually to the beer, and when the beer is neutralised, weigh the carbonate of soda remaining. Then calculate by rule of three.

As 53 is to the equivalent of the acid sought; so is the amount of carbonate of soda used to x; x = amount of acid in the quantity of beer operated upon.

The total acidity can be divided into fixed and volatile by evaporation. While the total acidity is being determined, evaporate another measured quantity of beer to one-fourth, then dilute with water, and determine the acidity. The acetic acid being volatile, is driven off, and lactic and other acids remain. Deduct the amount of alkaline solution used in this second process from the total amount used, and this will give the amounts used for the volatile and fixed acidities respectively; express one in terms of acetic, the other of lactic acid. The fixed acidity is greater than the volatile in almost all beers, and sometimes five or six times as much.

Generally speaking, the determination of total acidity of beer given in books are too great. I have seldom found it to be more than 30 grains per pint, and often less; sometimes not more than 14 or 15 grains.

4. *Determine Amount of Alcohol.*—There are various ways of doing this, but one of the two following will be sufficient.

Measure a certain quantity, say one pint, of beer, and take the specific gravity at 60° or 68° Fahr. 1*st*, Put into a retort and distil at least two-thirds. Take the distillate, dilute to original volume with distilled water, determine the specific gravity at 60° or 68° by a proper instrument, and then refer to the annexed table of specific gravities—opposite the found specific gravity the percentage of alcohol is given in volume (not in weight).

2*d*, Then, to check this, a plan devised by Mulder may be used. Take the beer in the retort, dilute with water to the original volume, and take the specific gravity at 60° or 68°.

Then deduct the specific gravity before the evaporation from the specific gravity after it, take the difference, and deduct this from 1000 (the specific gravity of water), and look in the table of specific gravities for the number thus obtained; opposite will be found the percentage of alcohol.* The results of these two methods should be identical.

* It may be puzzling at first to see how this plan gives the result; but it is simple enough. As alcohol is lighter than water, the evaporation raises the specific gravity in proportion to the

If there is no retort, this second plan may be used with a common evaporating dish, the alcohol being suffered to escape. A common urinometer (tested for correctness in the first place by immersion in distilled water at 62° Fahr.) may be employed for determining the specific gravity. The plan is very useful for medical officers; it requires nothing but a urinometer and evaporating dish.

Alcohol (Volume) according to Specific Gravity.

100 parts.		Specific Gravity.		100 parts.		Specific Gravity.	
Alcohol.	Water.	At 68°.	At 60°.	Alcohol.	Water.	At 68°.	At 60°.
50	50	0·914	0·917	24	76	0·966	0·968
49	51	0·917	0·920	23	77	0·968	0·970
48	52	0·919	0·922	22	78	0·970	0·972
47	53	0·921	0·924	21	79	0·971	0·973
46	54	0·923	0·926	20	80	0·973	0·974
45	55	0·925	0·928	19	81	0·974	0·975
44	56	0·927	0·930	18	82	0·976	0·977
43	57	0·930	0·933	17	83	0·977	0·978
42	58	0·932	0·935	16	84	0·978	0·979
41	59	0·934	0·937	15	85	0·980	0·981
40	60	0·936	0·939	14	86	0·981	0·982
39	61	0·938	0·941	13	87	0·983	0·984
38	62	0·940	0·943	12	88	0·985	0·986
37	63	0·942	0·945	11	89	0·986	0·987
36	64	0·944	0·947	10	90	0·987	0·988
35	65	0·946	0·949	9	91	0·988	0·989
34	66	0·948	0·951	8	92	0·989	0·990
33	67	0·950	0·953	7	93	0·990	0·991
32	68	0·952	0·955	6	94	0·992	0·992
31	69	0·954	0·957	5	95	0·994	0·994
30	70	0·956	0·958	4	96	0·995	0·995
29	71	0·957	0·960	3	97	0·997	0·997
28	72	0·959	0·962	2	98	0·998	0·998
27	73	0·961	0·963	1	99	0·999	0·999
26	74	0·963	0·965	0	100	1·000	1·000
25	75	0·965	0·967				

5. The solids can be determined by evaporation, and the ash obtained by incineration; but medical officers will seldom have occasion to do this. The specific gravity of the de-alcoholised beer gives a sufficient approximation.

6. Taste the beer evaporated to a syrupy consistence; it should be a pleasant bitter.

2. *Adulterations.*

1. *Water.*—Detected by taste; determining amount of alcohol and specific gravity of the beer free from alcohol.

2. *Alcohol.*—Seldom added; the quantity of alcohol is large in proportion to the amount of extract, as determined by the specific gravity after separation of the alcohol.

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loss of alcohol, and the gain of the beer in specific gravity from the evaporation is exactly equal to the depression in specific gravity which that amount of alcohol would cause if added to pure water equal in bulk to the beer operated upon.

3. *Sodium or Calcium Carbonate in order to lessen Acidity.*—Neither adulteration can be detected without a chemical examination. Evaporate beer to a thick extract, then put in a retort, acidulate with sulphuric acid, and distil; if calcium or sodium acetate be present, acetic acid in large quantity will pass over. The extract always contains some acetate, but only in small quantity.

Lime.—Evaporate to dryness another portion of beer, incinerate, dissolve in weak acetic acid, and precipitate by ammonium oxalate. In unadulterated beer the precipitate is moderate only.

Excess of soda, for some always exists in beer, is detected with much greater difficulty, and it will be well not to attempt this. Mulder states that the presence of too great a quantity of lactates may be determined by boiling the beer with zinc carbonate, when lactate of zinc deposits.*

4. *Sodium Chloride.*—This is hardly an adulteration, unless a very large quantity is added. Take a measured quantity of the beer; evaporate to dryness; incinerate; dissolve in water, and determine the chlorine by the standard solution of nitrate of silver. (See Analysis of Water.)

5. *Ferrous Sulphate.*—If the beer be light-coloured, a mixture of potassium ferricyanide and ferrocyanide (Faraday's test) may be added at once, and will give a precipitate of Prussian blue; if the beer be very dark-coloured, it must be decolorised by adding solution of lead diacetate and filtering.

Or evaporate a portion of beer to dryness and incinerate; if any iron be present the ash is red; dissolve in weak nitric acid, and test with potassium ferrocyanide. Two grains of ferrous sulphate to nine gallons of water give a red ash (Hassall). The ash of genuine porter is always white, or greyish white (Hassall).

6. *Sulphuric acid* is added to clarify beer, and to give it the hard flavour of age. If the beer be pale, add a few drops of hydrochloric acid, and test with barium chloride. A *very dense* precipitate may show that sulphuric acid has been added, but it must be remembered that the water used in brewing may contain large quantities of sulphates. (The Burton spring water is rich in calcium sulphate.) If there be a *large* precipitate, then determine the acidity of the beer before and after evaporation; if the amount of fixed acid be found to be *very* large, there will be no doubt that sulphuric acid has been added, or precipitate with baryta and weigh. (See Water).

Mulder recommends that the extract of the beer be heated, and the sulphurous acid gas which is disengaged led into chlorine water; sulphuric acid will be found in the chlorine water, and may be tested for as usual.

7. *Alum.*—Evaporate to dryness; incinerate, and proceed exactly as in the analysis of alum in bread. The substance added to give "head" to beer is a mixture of alum, salt, and ferrous sulphate.

8. *Burnt Sugar—Essentia bina.*—Evaporate beer to extract; dissolve in alcohol; evaporate again to extract, and taste. According to Pappenheim, these substances prevent the regressive metamorphosis of the tissues, and thus injure health. Burnt sugar is added to porter to give colour, and the addition is not illegal.

9. *Capsicum—Peppers—Grains of Paradise.*—Evaporate to dryness carefully; dissolve in alcohol; filter; evaporate very carefully to dryness, and taste if there is any pungency. In fourteen out of twenty samples of illicit beer, Mr Phillips found that grains of paradise had been added.

10. A number of other substances are, it is said, sometimes added,—centauria, absinthe, pyrethrus, gentian, quassia, aloes, burnt chicory. The

* De la Bière (French edition), 1861, p. 363.

detection is extremely difficult, if not impossible, unless the taste of the alcoholic extract gives any indication.

11. *Cocculus Indicus.*—It is not known whether much of this is now used. The witnesses examined some years ago (1856) by the Committee of the House of Commons (Scholefield's) all doubted it; a large quantity of *Cocculus indicus* is, however, annually imported, and no other use is known. In two instances out of twenty specimens of adulterated beer, analysed in 1863 by Mr Phillips, *Cocculus indicus* was found in large quantities.

For the detection of Picrotoxine, Herapath recommends that the beer be first treated with lead acetate; filtered; excess of lead got rid of by sulphuretted hydrogen; fluid evaporated to a small bulk, and mixed with animal charcoal. The charcoal absorbs the picrotoxine; it is boiled in alcohol, and the alcohol is evaporated on slips of glass. The picrotoxine crystallises as plumose tufts of circular or oat-shaped crystals.

Dr Langley of Michigan* recommends acidulating the beer with hydrochloric acid and agitating with ether; the etherial solution yields on evaporation crystals of picrotoxine, which can be tested by rubbing it with nitrate of potash; adding a drop of sulphuric acid, and then a strong solution of potash of soda. A bright reddish-yellow colour is given if picrotoxine be present.

A more complete, but much longer process, is given by Schmidt,† who detected ·04 grains of picrotoxine in a bottle of beer; but probably one of the above will be sufficient.

12. *Strychnine* or *Nux Vomica.*—This is a very uncommon adulteration, if it ever occur. Add animal charcoal to the beer; digest for twenty-four hours; pour off beer; boil the charcoal in alcohol; filter; evaporate one-half; add a few drops of liquor potassæ and then ether; agitate; pour off ether, and evaporate to dryness; test for strychnine by the colour tests (sulphuric acid and bichromate of potash, or peroxide of lead, or manganese, or potassium permanganate).

13. *Tobacco* is occasionally used; in twenty specimens of illicit beer examined in 1863, by Mr Phillips of the Inland Revenue department, tobacco was found in one.

14. *Picric (Trinitrophenic) Acid.*—Lassaigne recommends the addition of subacetate of lead and animal charcoal; if the beer has still a yellow colour, picric acid is present. But, as Mulder and Hassall observe, many beers destitute of picric acid remain yellow. Pohl advises to add white uncombed wool; if picric acid be present it stains it. This is an uncertain test.

15. *Copper.*—Evaporate a portion of the beer to dryness; incinerate; dissolve in weak nitric acid; test for copper by the insertion of a clean knife; by addition of ammonia and of potassium ferrocyanide.

16. *Lead.*—Evaporate a considerable quantity of the beer to dryness; incinerate; dissolve in weak nitric acid, and test for lead as usual. (See Analysis of Water.)

SUB-SECTION II.—WINES.

Composition.

The composition of wine is so various that it is difficult to give a summary. The following are the chief ingredients:—

1. *Alcohol.*—From 6 to 25 per cent. of volume of anhydrous alcohol. It has been, however, stated that the fermentation of the grape, when properly

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* Chemical News, Sept. 6, 1862.
† Schmidt's Jahrb. 1863, No. 4, p. 5; and Chemical News, March 1864, p. 123.

done, cannot yield more than 17 per cent., and that any amount beyond this is added.* Some of the finest wines do not contain more than 6 to 10 per cent.

	Per cent. of Alcohol (Volume).	
Port (*analysed in England*), ...	16·62† to	23·2
Sherry (*analysed in England*), ...	16 ,,	25
Madeira (*analysed in England*), ...	16·7 ,,	22
Marsala (*analysed in England*), ...	15 ,,	25
Bordeaux wines, red (mean of 30 determinations of different sorts: Chateau Lafite, Margeau, Larose, Barsac, St Emilion, St Estèphe, &c.), . .	6·85 ,,	13
Bordeaux wines, white (mean of 27 determinations of sorts: Sauterne, Barsac, Bergerac, &c.), .	11 ,,	18.7
Rhone wines, red (Hermitage, Montpellier, Frontignan, &c.), ...	8·7 ,,	13·7
Rousillon, ...	11 ,,	16
Burgundy, red (Beaune, Maçon), ...	7·3 ,,	14·5
,, white (Chablis, Maçon, Beaune), . .	8·9 ,,	12
Pyrennean, ...	9 ,,	16
Champagnes, ...	5·8 ,,	13
Moselles, ...	8 ,,	13
Rhine wines (Johannisberg, Hochheimer, Rudesheimer, &c.), ...	6·7 ,,	16
Hungarian wine, ...	9.1 ,,	15
Italian, ...	14 ,,	19
Syria, Corfu, Samos, Smyrna, Hebron, Lebanon, .	13 ,,	18

So various is the amount of alcohol in wines from the same district, that a very general notion only can be obtained by tables, and a sample of the wine actually used must generally be analysed.

To tell how much pure alcohol is taken in any definite quantity of wine, measure the wine in ounces, and multiply it by the percentage of alcohol with a decimal point before it.

Example.—Wine drank being 9 oz., and the percentage 13, then 9 × 13 = 1·17 oz. of absolute alcohol.

The amount of alcohol can be determined by distillation or evaporation, as given in the section on Beer.‡ Instruments, however, are required, which indicate a less specific gravity than pure water. If the medical officer has only a common urinometer, the only plan will be to dilute with an equal part of pure water at 60°, and then to add a little salt, so as to bring the specific gravity above that of water; then evaporate as usual. Take the difference of the specific gravities (before and after evaporation); deduct from 1000, and look in the table (p. 254) for the amount of alcohol in the diluted wine; by multiplying the result by 2, the percentage of alcohol in the undiluted wine is found.

2. *Ethers.*—Œnanthic, citric, malic, tartaric, racemic, acetic, butyric, caprilic, caproic, pelargonic, and many others. Dr Dupré states that there

* Mulder (on Wine, p. 186) quotes Guijal to the effect that pure port never contains more than 12·75 per cent. of pure alcohol; but Mulder doubts this. Dr Gorman stated before the Parliamentary Committee that pure sherry never contains more than 12 per cent. of alcohol, and that 6 or 8 gallons of brandy are added to 108 gallons of sherry.

† Some port used in the Queen's establishment contains only 16·62, and the highest percentage is 18·8 (Hofmann). The sherry contains only 16 per cent., and the claret 6·85 to 7 per cent.

‡ Geissler's vaporimeter is an excellent plan when there are many analyses to be made, but the instrument is too delicate to be carried about.

are 25 or even more compound ethers in wine, and some of them are in very small quantities. The "bouquet" of wine is partly owing to the ethers (especially the volatile)—partly, it is said, to extractive matters. Dr Dupré has given a very good plan of estimating the amount of the volatile and non-volatile ethers, but it is too delicate for medical officers.*

3. *Albuminous Matters—Extractive Colouring Matter.*—The quantity of albumen is not great; the extractives and colouring matter vary in amount. The colouring matter is derived from the skins; it is naturally greenish or blue, and is made red by the free acids of wine. The bluish tint of some Burgundy wines is owing, according to Mulder, to the very small amount of acetic acid which these wines contain. It is, according to Batilliat, composed of two matters—rosite and purpurite. With age changes occur in the extractive matters; some of it falls (apothema), especially in combination with tannic acid, and the wine becomes pale and less astringent.

4. *Sugar* exists in varying amounts, and in the form for the most part of fruit sugar. Sherry generally contains sugar, but not always; it averages 8 grains per ounce,† and appears to be highest in the home sherries, and least in Amontillado and Mazanilla. In Madeira it varies from 6 to 66 grains per ounce; in Marsala a little less; in port, from 16 to 34 grains per ounce, being apparently greatest in the finest wine. In champagne it amounts to from 6 to 28 grains, the average being about 24 grains. In the clarets, Burgundy, Rhine, and Moselle wines, it is absent, or in small amount.

The amount of sugar is best determined by the saccharometer. If the copper solution (p. 237) be used, the colouring matter is acted on by the alkali of the copper solution, and interferes with the appreciatian of the change of tint, and must be got rid of by acetate of lead only, animal charcoal, boiling, and filtering. If any substance exists which is still turned green by the alkali of the copper solution, the wine must be neutralised, evaporated to dryness, and the sugar dissolved. As a rule, the copper solution employed directly with wine gives often $\frac{1}{2}$ per cent. too much sugar (Fehling), and a correction to this amount should be made.

5. *Fat.*—A small amount exists in some wine.

6. *Free Acids.*—Wine is acid from free acids and from acid salts, as the bitartrate of potash. The principal acids are racemic, tartaric, acetic, malic, tannic (in small quantities), glucic, formic (?), lactic (?), carbonic and fatty acids. Some acids are volatile besides the acetic, but it does not seem quite certain what they are. The tannic acid is derived from the skins; it is in greatest amount in new port wine; it is trifling in Madeira and the Rhine wines; it is present in all white and most red-fruit wines, except champagne. The tannic acid on keeping precipitates with some extractive and colouring matter (apothema of tannic acid).

7. *Determination of the Free Acidity.*—This is done by the alkaline solution, as described in the section on Beer, or if this is not procurable, the dried carbonate of soda can be used. The free acidity is generally reckoned as crystallised tartaric acid ($C_4H_6O_6$). There is both fixed and volatile acidity; the relative amount of the two is difficult to determine satisfactorily, as some acid may be formed on distillation. The distillation should be conducted at a low temperature, so as not to decompose the fixed compound ethers.

The amount of free acidity varies greatly even in the same kind of wines; the least acid wines are sherry, port, champagne, the best claret, and Madeira; the more acid wines are Burgundy, Rhine wine, Moselle (Bence Jones). The

* Chem. Journal, Nov. 1867.
† Bence Jones in "Mulder on Wine," p. 386.

amount of free acid in good claret is equal to 2 or 4 grains per ounce of tartaric acid; in common clarets, and in Beaujolais, it may be 4 to 6 grains, and in some extremely acid wines it may be even more than this. In the best champagnes it is 2 to 3 grains usually; but it has been known to reach in excellent champagne 1·12 per cent., or 4·8 grains per ounce.* In port it averages 2 to 2½ grains, but may reach 4 grains; in sherry, 1½ to 2¼ grains; in the Rhine wines, 3½ to 4 or 6 grains.

The taste of wine does not depend on, but yet is somewhat influenced by the degree of acidity. Still the taste and juice of a wine can never be judged of by the acidity. Mr Griffin† states that good-tasted wine contains from 1·87 to 2·8 grains of crystallised tartaric acid per ounce; that if it contains less than 1·87 grains it tastes flat; that if more than 3 grains per ounce, the wine is too acid to be agreeable; if more than 4·37 grains per ounce, it is too acid to be drunk. These numbers are rather lower than I should have supposed.

8. *Salts.*—The salts consist of bitartrate of potash, tartrate of lime and soda, sulphate of potash, a little phosphate of lime and magnesia, chloride of sodium, and iron. The magnesia is in larger amount than the lime, and exists sometimes as malate and acetate. A little manganese and copper have been sometimes found. In Rhine wine a little ammonia is found (Mulder). The total amount of salts is ·1 to ·3 per cent.—*i.e.*, about 9 to 26 grains per pint, or ½ to 1½ grain per ounce. The salts can only be detected by evaporation and ignition.

The total solids in wine vary from 3 to 14 per cent., or in some of the rich liqueur-like wines to more. The specific gravity depends upon the amount of alcohol and of solids, and varies from ·973 to 1·002 or more. An approximate notion can be formed of the total solids by taking the specific gravity, after driving off the alcohol by evaporation, and then replacing the water (see Beer, p. 250).

The quality of wine can be best determined by noting the colour, transparency, and taste, and then determining the following points:—

(1.) The amount of solids as given by the specific gravity after the elimination of the alcohol. In the best clarets, before the loss of alcohol, the specific gravity is very nearly that of water. In some claret used in the Queen's establishment, and analysed by Dr Hofmann, the specific gravity was ·99952. In inferior clarets it is as low as ·995. The low specific gravity shows that alcohol has been added, or that the solids are in small amount.

(2.) The amount of alcohol; a very small amount may show the addition of water; a large amount the addition of spirits.

(3.) The amount of free acidity. This is an important point, as it seems clear that some persons (especially the sick) do not readily digest a large amount of acid and acid salts.

(4.) The amount of sugar. The best mode of determining this has been already noticed.

(5.) It may be sometimes useful to determine the amount and kind of ethers by fractional distillation.

Excessive acidity of wine can be corrected by adding neutral tartrate of potash. Milk is also often used. The addition of the carbonated alkalies, or of chalk, alters the bouquet of the wine. When wine becomes stringy, in which case acetic and lactic acids are formed, it may be improved by adding a little tea; about 1 ounce of tea boiled in 2 quarts of water should be added to about 40 gallons of wine. Bitter wine is treated with hard water or sul-

* This was the case in some champagne examined by Dr Hofmann.
† Report on Cheap Wine, by R. Druitt, M.D., p. 178.

phur; bad smelling wine with charcoal; too astringent wine with gelatine; wine which tastes of the cask with olive oil.*

Adulterations of Wine.

1. *Water.*—Known by taste; amount of alcohol; specific gravity after elimination of alcohol.

2. *Distilled Spirits.*—Known by determining the amount of alcohol; the normal percentage of the particular kind of wine being known. By fractional distillations the peculiar-smelling fusel oils may be obtained; or merely rubbing some of the wine on the hand, and letting it evaporate, may enable the smell of these ethers to be perceived.

3. *Artificial Colouring Matters.*—There are no good methods of recognising these matters; salts of lead, ammonia, and ammonium sulphide, alum, and potassium or ammonium carbonate, salts of tin, have been used as re-agents. The most useful test appears to be this: add to the wine about $\frac{1}{4}$th volume of strong solution of alum; stir well, and then add about an equal quantity of strong solution of ammonium carbonate; the natural colouring matter of the wine when thrown down in this way has a greenish or dirty bluish-green colour, but there is no tinge of red; logwood and several other abnormal colours have a distinct red or purplish tint.†

4. *Lime Salts.*—The so-called "plâtrage" of wines consists in the addition of $1\frac{1}{2}$ ℔ to 7 ℔ of a mixture of sulphate of lime (80 parts), carbonate of lime (12), quicklime and sulphide and chloride of calcium (8 parts) to 1 hectolitre of wine. Sulphate of lime dissolves in large proportion, and then interchanges with the chloride of potassium, and chloride of calcium and sulphate of potash are formed. The chalk forms acetate and tartrate of lime. The proportion of lime salts is then very large. The only precise way of detecting this adulteration is by evaporating to dryness, incinerating, and determining the amount of lime. But the following method is shorter, and will generally answer. The natural lime salts of wine are tartrate and sulphate; when lime is added an acetate of lime is formed. Evaporate the wine to $\frac{1}{10}$th; add twice the bulk of strong alcohol; the acetate of lime is dissolved, but not the sulphate or tartrate; filter and test with oxalate of ammonia; if a large precipitate occur, lime has probably been added.

5. *Tannin* may be detected either by chloride of iron or by adding gelatine. But as tannin exists naturally in most of the red wines (Port, Beaune, Roussillon, Hermitage, &c.), the question becomes often one of quantity. The amount of tannin can be estimated by drying the tannogelatine (100 grains contain 40 of tannin).

6. *Alum.*—This is detected precisely in the same manner as in bread. Evaporate a pint of the wine to dryness; incinerate, and then proceed as directed in bread.

7. *Lead.*—Evaporate to dryness, and incinerate; dissolve in dilute nitric acid, and test as directed under the head of WATER.

8. *Copper.*—Decolorise with animal charcoal, and test at once with ferrocyanide of potassium.

9. *Cider and Perry.*—Evaporate wine, and the peculiar smell of the liquids will be perceived.

Port wine, as sold in the market, is stated to be a mixture of true Port,

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* Wine is subject to several diseases, which, according to Pasteur, depend on different kinds of ferments (see Review of Hygiene in Army Medical Department Report, vol. vii. p. 340). By heating the wine to about 125° to 131° Fahr. these "mycodermes" are killed, and the wine undergoes no change.

† Mulder speaks very doubtfully of all such tests; they seem, however, better than nothing.

Marsala, Bordeaux, and Cape wines with brandy. Inferior kinds are still more highly adulterated with logwood, elderberries, catechu, prune juice, and a little sandalwood and alum. Receipts are given in books for all sorts of imitation wines.

Wine as an Article of Diet.

So complex and so varying is the composition of many kinds of wine, that it seems almost impossible to make any statements which shall be applicable to all sorts. But it is clear that wine contains, besides alcohol and ethers, several substances of great value as articles of diet, viz., some albuminous substances, much sugar in some wines, and other carbo-hydrates, and abundant salts. The common experience of nations seems to prove that the employment of wine in moderation is useful as well as agreeable. Whether it is that the amount of alcohol is small, or whether the alcohol be itself, in some way, different from that prepared by distillation, or whether the co-existence of carbo-hydrates and of salts modifies its action, certain it is that the moderate use of wine, which is not too rich in alcohol, does not seem to lead to those profound alterations of the molecular constitution of organs which follow the use of spirits, even when not taken largely. Considering the large amounts of vegetable salts which most wines contain, it may reasonably be supposed that they play no unimportant part in giving dietetic value to wine. Indeed, it is quite certain that, in one point of view, they are most valuable; they are highly anti-scorbutic, and the arguments of Lind and Gillespie, for the introduction of red wine into the royal navy instead of spirits, have been completely justified in our own time by both French and English experience. It is now certain that with the same diet, but giving in one case red wine, in another rum, the persons on the latter system will become scorbutic long before those who take the wine. This is a most important fact, and in a campaign, the issue of red wines should never be omitted. The ethers may also be important if, as indicated by Bernard, and recently pointed out by Dr B. Foster (British Med. Journal, Nov. 1868), they excite the flow of the pancreatic secretion, and thereby promote the absorption of fat.

To define precisely what is moderation in the use of wine is as impossible as in the case of beer; that most persons, even in these days of comparative temperance, take too much is highly probable. After all, a point of this kind must be settled by individual experience. The great object should be to discourage the use of the strong wines (15 to 23 per cent. of alcohol), and to encourage the use of the weak wines (6 to 10 per cent. of alcohol). There is, of course, no doubt that wine is unnecessary as an article of diet, and many persons are much better without it.

Sub-Section III.—Spirits.

The Queen's Regulations for the Army (1868, sec. 1010), forbid the sale of spirits in canteens at home, but permit it in foreign stations at the option of the commanding officer.

Brandy contains, besides alcohol, œnanthic ether, acetic, butyric, and valerianic ethers. Tannin and colouring matter from the cask, or from caramel, are present. If sugar is present in any quantity, it must have been added. The inferior kinds of brandy, prepared from potatoes as well as grain, contain potato fusel-oil. Rum contains a good deal of butyric ether, to which the aroma is chiefly owing. Gin, besides containing the oil of juniper, is flavoured with various aromatic substances,—as *Calamus aromaticus*, coriander, cardamoms, cinnamon, almond-cake, and orange-peel; Cayenne is often added.

Whisky often derives a peculiar flavour from the malt being dried over peat fires, or by the direct impregnation of peat smoke.*

Composition of Spirits.

The following table gives the chief points of importance :—†

Name.	Sp. Gr.	Alcohol, per cent.	Solids, per cent.	Ash, per cent.	Acidity per ounce, reckoned as tartaric acid.	Sugar, per cent.
Brandy, . .	·929–·934	50–60	1·2	·05 to ·2	1 grain	0 or traces
Gin, . . .	·930–·944	49–60	·2	·1	0·2	1
Whisky, . .	·915–·920	50–60	·6	trace	0·2	0
Rum, . . .	.874–·926	60–77	1·	·1	0·5	0

Spirits as an Article of Diet for Healthy Persons.‡

Three sets of arguments have been used in discussing this question, drawn, namely, from—

1. The physiological action of alcohol.
2. Experience of its use or abuse.
3. Moral considerations.

To the last point I shall not further allude, for though I do not underrate the great weight of the argument drawn from the misery which the use of alcohol produces,—a misery so great that it may truly be said, that if alcohol were unknown, half the sin and a large part of the poverty and unhappiness in the world would disappear,—yet this part of the subject is so obvious that I do not wish to occupy space with it. To my mind, however, the arguments which are strongest for total abstinence are drawn from this class. Nor does any one entertain a moment's doubt that the effect of intemperance in any alcoholic beverage is to cause premature old age, to produce or predispose to numerous diseases, and to lessen the chance of living very greatly. The table given below,§ taken from Neison's "Vital Statistics," puts this in a strong light.

* It may be worth while to give the names of some of the distilled spirits used in different parts of the world, as the army surgeon may meet with them in the course of service :—

Nations by whom employed.	Name.	Obtained from.
Hindus, Malays, &c.,	Arrack.	Rice or Areca-nut.
Greeks, Turks, &c.,	Raki.	Rice.
Hindus,	Toddy.	Cocoa-nut.
,, (Mahrattas),	Bojah.	Eleusine Corocana.
,, (Sikkim),	Murwa.	,, ,,
Chinese,	Samshoo.	Rice.
Japanese,	Sácie.	...
Pacific Islanders,	Kawa.	Macropiper.
Mexicans,	Pulque.	Agave.
South Americans,	Chica.	Maize.
Tartars,	Kommiss.	Mares' milk.
Russians and Poles,	Vodki.	Potato.
Abyssinians,	Tallah.	Millet.

† This table is chiefly taken from Bence Jones' "Observations;" "Appendix to Mulder on Wine," p. 389; and from Hassall's "Food and Adulterations," p. 645.

‡ The subject of spirits in sickness is another point altogether. I believe they are often of great use, although, like every other strong medicine, they require to be given carefully. The fashionable plan of giving great quantities of strong spirits is happily dying out, and is being replaced by a more careful practice.

§ Effects of intemperance, Neison's "Vital Statistics," p. 217, *et seq.* :—

The Physiological Action of Alcohol, taken as an Article of Diet, and not as a Remedy in Disease.

Any physiological argument for the use or disuse of spirits requires to be used with caution, as our knowledge of the action of pure alcohol (much more of the alcoholic beverages) is imperfect.

When taken into the stomach, alcohol is absorbed without alteration, or is perhaps in some small degree converted into acetic acid, possibly by the action of the mucus or secretion of the stomach. The rate of absorption is not known, and it has been supposed that when given in very large quantities it may not be absorbed at all. As far as I am aware, it has not, however, been recovered from the fæces in any great amount. After absorption it passes into the blood and then throughout the body; if the observations of Schulinus* are correct, it is equally distributed, and does not accumulate, as was formerly supposed, in the liver and nervous tissue. It commences to pass out from the body speedily, as it may be detected in the breath soon after it is taken; it emerges chiefly by the lungs, partly by the skin, in smaller quantities by the urine, and slightly by the bowels, or this may be merely from unabsorbed portions passing out. The amount recoverable from the urine is usually small,† and occasionally it passes in large quan-

Ratio per cent. from the under-mentioned Causes, to Deaths from all Causes.

Cause of Death.	1847.	Gotha Life Office.	Scottish Widows' Fund.	Intemperate Lives.
Head diseases, ...	9·710	15·176	20·720	27·10
Digestive organs (especially those of the liver), ...	6·240	8·377	11·994	23·3
Respiratory organs, ...	33·150	27·843	23·676	22·98
Total of above three classes,	49·100	51·396	56·390	73·38

It thus appears that the intemperate have a much greater mortality from head and digestive diseases than other classes.

In intemperate persons the mortality at 21–30 years of age is five times that of the temperate; from 30–40 it is four times as great. It becomes gradually less.

A Temperate person's chance of living is,	An Intemperate person's chance living is,
At 20 = 44·2 years.	At 20 = 15·6 years.
,, 30 = 36·5 ,,	,, 30 = 13·8 ,,
,, 40 = 28·8 ,,	,, 40 = 11·6 ,,
,, 50 = 21·25 ,,	,, 50 = 10·8 ,,
,, 60 = 14·285 ,,	,, 60 = 8·9 ,,

All these deductions appear to be drawn from observations on 357 persons with 6111·5 years of life. The facts connected with these persons are well authenticated, but the number is small. The average duration of life after the commencement of the habits of intemperance is—

Among mechanics, working and labouring men, ...	18 years.
,, traders, dealers, and merchants, ...	17 ,,
,, professional men and gentlemen, ...	15 ,,
,, females, ...	14 ,,

Those who are intemperate on spirits have a greater mortality than those intemperate on beer. Those who are intemperate on spirits and beer have a slightly greater mortality than those intemperate on only spirits or beer, but the difference is immaterial.

	Mortality per Annum.
Spirit drinkers, ...	5·996 per cent. (nearly 60 per 1000).
Beer drinkers, ...	4·597 per cent. (nearly 46 per 1000).
Spirit and beer drinkers, . . .	6·194 per cent. (nearly 62 per 1000).

* Archiv der Heilk., 1866, p. 97.

† Experiments on this point by Schulinus, Anstie, and Dupré, Thudichum, and others, prove that ordinarily the urinary elimination is slight. When it becomes at all marked, or even when it occurs at all, the detection of alcohol by potassium bichromate and sulphuric acid has been proposed by Anstie as an indication of the point when as much alcohol has been taken as can be disposed of by the body.

tities, so that the specific gravity of the urine has been below that of water, and distillation has given an inflammable fluid.*

Much debate has taken place as to whether all or nearly all the alcohol is thus eliminated, or whether any is destroyed in the body. The experiments of Dr Percy, and subsequently of Strauch, and especially of Masing in Buchheim's laboratory at Dorpat, followed as they were by the confirmatory observations of MM. Perrin, Lallemand, and Duroy, seemed at one time to have settled the question, and to have proved that alcohol is very little or not at all destroyed in the body. Since then the criticisms and experiments of Baudot, and especially the observations of Schulinus,† and of Anstie,‡ have again altered the position, and although the experimental evidence is incomplete (chiefly on account of the difficulty of collecting the amount given off by the lungs and skin), the opinion that alcohol disappears in the body is probably correct.§

It seems probable that both the power and the rate of destruction are moderate, and that alcohol soon begins to accumulate in the body; certainly, it can sometimes be recovered from some fluids (as in the ventricles of the brain), even days after the last quantity has been taken. The question of its destruction, however interesting, is not the most important point; it is much more necessary to know what effects it has (whether eventually destroyed or not) on the blood and the various tissues.

1. *On the Stomach.*—In very small quantities it appears to aid digestion; in larger amount it checks it, reddens the mucous membrane, and produces the "chronic catarrhal condition" of Wilson Fox, viz., increase of the connective tissue between the glands; fatty and cystic degeneration of the contents of the glands, and, finally, more or less atrophy and disappearance of these parts.|| Taken habitually in large quantities, it lessens appetite.

2. *On the Liver.*—The action of small quantities on the amount of bile or glycogenic substances, or on the other chemical conditions of the liver, is not known. Applied directly to the liver by injection into the portal vein, it increases the amount of sugar (Harley). Taken daily in large quantities, it causes either enlargement of the organ by producing albuminoid and fatty deposit, or it causes at once, or following enlargement, increase of connective tissue, and finally, contraction of Glisson's capsule, and atrophy of the portal canals and cells, by the pressure of a shrinking exudation. The exact amount necessary to produce these changes in the liver and stomach has not yet been fixed with precision.

3. *On the Spleen.*—Its action is not known.

4. *On the Lungs.*—It lessens the amount of carbonic acid (and of watery vapour?) in the air of expiration, and this is probably true of all the alcoholic beverages,¶ though there are some discrepancies in experiments with different kinds of spirits (E. Smith, who found the expired carbonic acid

* A good case is given by Dr Woodman (Medical Mirror, July 1865).

† Archiv der Heilk., 1866.

‡ *Lancet*, 1868.

§ The experiments of Schulinus on animals seem very strong; he could never recover from the urine and the body of the animal anything like the quantity taken in; still we must remember the extreme difficulty of such an experiment.

|| These changes are now considered by Wilson Fox to be closely allied with those occurring in cirrhosis of the liver, and in the contracted and indurated kidney. Dr Fox informs me that the association of those conditions in these organs "has been before him with remarkable frequency." See also Reynold's System of Medicine, vol. ii. p. 869, and footnote.

¶ The effect of red and white French wines and of beer has been lately very carefully examined by Perrin (Rec. de Mém. de Méd. Mil. 1865, p. 82); a very great diminution in the amount of carbonic acid (from 5·6 to 22 per cent., less being excreted) was noticed in all the experiments. The effect commenced soon, and reached its maximum in the third hour, and ceased in two hours more. The pulse after meals with and without wine had equal power, but after a time the pulse fell more when wine was not taken.

lessened by brandy and gin, but increased by rum). In large quantities habitually taken it also alters the molecular constitution of the lungs, as chronic bronchitis and lobar emphysema are certainly more common in those who take much alcohol.

5. *On the Heart and Blood-Vessels.*—Alcohol usually at first increases the force and sometimes the quickness of the heart's action. Dr Anstie* has lately confirmed this opinion by careful sphygmographic observations, and has shown that it also increases the arterial tension; these effects are still more marked in febrile diseases if alcohol acts favourably (in some febrile cases it appears, from Anstie's observations, not to increase the power of the heart). Eventually, it would appear from other observations, that it tends to lower the heart's action, and partially paralyses the vaso-motor nerves, so that there is general turgescence of the blood-vessels. Anstie believes its principal action is on the sympathetic, and the vascular phenomena seem to strengthen this view, while others think it acts especially on the vagus and the heart alone. In large quantities habitually taken it perhaps alters molecular constitution, and tends to the deposit or the formation of fat, as well as perhaps to other parenchymatous changes. It causes general turgescence, especially of the skin, apparently from a sort of paralysing action on the nerves of the small arteries.

6. *On the Blood.*—The amount of fat is either increased, or it is more visible. The chemical changes in the blood are partially arrested.†

7. *On the Nervous System.*—In most persons it acts at once as an anæsthetic, lessening the rapidity of impressions, the power of thought, and the perfection of the senses. In other cases it seems to cause increased rapidity of thought, and excites imagination, but even here the power of control over a train of thought is lessened. In no case does it seem to increase accuracy of sight; nor is there any good evidence that it quickens hearing, taste, smell, or touch; indeed, Edward Smith's experiments show that it diminishes all the senses. In almost all cases moderate quantities cause a feeling of comfort and exhilaration, which ensues so quickly as to make it probable the local action on the nerves of the stomach has at first something to do with this. Afterwards the increased action of the heart may have an effect. Different spirits act differently on the nervous system, owing probably to the presence of the ethers; some, as samshoo and raki, produce great excitement, followed by profound torpor and depression. Absinthe is also especially hurtful, apparently from the presence of the essential oils of anise, absinthe, and angelica, as well as from the large amount of alcohol. It appears that the properties are somewhat different according to the manner in which water is mixed with the absinthe, *i.e.*, suddenly or slowly; in the latter case, the articles of the absinthe are more divided, are absorbed more easily, and produce greater effects. In all these cases there can be little doubt that it enters into temporary combination with the nervous structure; and the evidence from the impairment of special sense and muscular power, implies that it interferes with the movements of the nervous currents.

8. *On the Muscular System.*—Voluntary muscular power seems to be lessened, and this is most marked when a large amount of alcohol is taken at once; the finer combined movements are less perfectly made. Whether this is by direct action on the muscular fibres, or by the influence on the nerves,

* In a paper read before the British Association in 1868 (Medical Times and Gazette, September 1868). This paper shows that the sphygmographic indications (combined with the urinary test), may give us a clue to the often difficult question, whether alcohol is doing good or harm in disease.

† Harley. Proceedings of Royal Soc., March 1864, No. 62, p. 160.

is not certain. In very large doses it paralyses either the respiratory muscles, or the nerves supplying them, and death sometimes occurs from the impairment to respiration.

9. *On the Metamorphosis of Tissue.*—This is lessened, as is evidenced by a diminution in the elimination of nitrogen (as urea), and of carbon (as carbonic acid). This indicates that less mechanical force is produced in the body, and less work is got from the human machine. Large quantities of alcohol, therefore, tend to cause an accumulation in the system of imperfectly oxidised bodies, such as uric and oxalic acids.

10. *On the Temperature of the Body.*—Perrin, to whose observations reference has been made, found the temperature of the body rather less after meals with, than after meals without wine. Drs Sidney Ringer, and Rickards have made an extensive series of observations on men and rabbits, which show that alcohol in large doses depresses the temperature remarkably. In dietetic doses it also usually lowers it. These experiments are quite in accordance with the observations on the use of alcohol when persons are exposed to cold (see next page).

11. *On the Action of the Eliminating Organs.*—The action of the lungs and kidneys is lessened; less carbonic acid, less urea, and less water are eliminated; the condition of the skin is not certain. Dr Edward Smith thinks it is lessened, and there is apparently dryness of the skin after the use of alcohol. But Weyrich* has noticed after spirits, beer, and wine, a very large augmentation of the insensible cutaneous perspiration. When taken habitually in large quantities the minute structure of the kidneys suffers, the vessels and tubes become thickened, and there is proliferation and rapid cell-growth, followed by as rapid atrophy and shrinking. It has also been often noticed that even moderate spirit drinkers show very early an appearance of age, and this probably arises from the constant over-distension of the small vessels of the skin, and perhaps from some change in the texture of the skin itself.

It is certainly undesirable to draw any strong conclusions as to the use of alcohol in health, from our present knowledge of its physiological action, but it is impossible not to feel, that so far the progress of physiological inquiry renders the propriety of the use of alcohol in health more and more doubtful.

It appears to decrease strength and to impair nutrition, by hindering oxidation, and if in large quantities, the reception of food; while habitually taken in any large quantity, it leads to degeneration of the tissues of certain organs, especially of the liver, the nervous system, the heart, lungs, and kidneys. If we look upon the body as an agent of work, from which we desire to obtain as much mechanical and mental force as is compatible with health, we can consider the effect of alcohol, *per se*, as simply a means of preventing this development of force. But physiological experiment does not yet point out what quantity is necessary to produce these effects, nor whether a high degree of dilution, or the admixture of other substances, may not to a certain extent counteract the action of pure alcohol.

The Arguments from Experience for and against the use of Alcohol in Health, are at present our chief guides.

Beer and the weaker wines contain other ingredients which are useful, and when used in moderation the quantity of alcohol is small. Experience does not show at present any increase of sickness, proneness to special diseases, or lessening of duration of life in those who take moderately of beer or the weaker wines. In some cases, indeed, the moderate use seems to increase

* Die unmerkliche Wasserverdunstung der Menschl. Haut. Von Dr V. Weyrich, 1862, p. 117.

appetite and improve nutrition. But, on the other hand, experience most decidedly shows that the highest health, the greatest vigour, and long life, are quite compatible with entire abstinence from these liquids.

In the case of spirits the result of experience is very different, and I believe it may be asserted that experience does not sanction the use of spirits; or if in health their employment is useful, it can only be, I believe, in quite exceptional circumstances, viz., when either a sudden stimulant is necessary for a failing heart, or when, in cases of deficient food, it is desired to lessen as far as possible the waste of the body, or to diminish mental power, and the undue excitability of the nervous system.

*Evidence on the Use of Spirits under various circumstances.**

Great Cold.—There is singular unanimity of opinion on this point; all observers condemn the use of spirits, and even of wine or beer, as a preventive against cold. In the Arctic regions we have on this head the evidence of Sir John Richardson, Mr Goodsir (in Sir J. Franklin's first voyage), Dr King, Captain Kennedy (in the last search for Sir J. Franklin, when the whole crew were teetotallers), Dr Kane, Dr Hayes (surgeon of the Kane expedition), and others. Dr Hayes, indeed, says in his last paper (1859), that he will not only not use spirits, but will take no man accustomed to use them; and that if "imperious necessity obliges him to give spirits, he will give them in small doses frequently, as the excitant action is followed by a very dangerous depression." In the Antarctic regions, and in the cold whaling grounds, we have the strong evidence of Dr Hooker to the same purport, and the customs of the many teetotal whalers. Ulloa long ago noticed the same thing in the ascent of Pichincha.† In North America, the Hudson's Bay Company entirely excluded spirits, partly, no doubt, to prevent their use among the Indians, but partly, in all probability, from experience of their inutility. Dr Carpenter quotes from Dr Knüll a statement, that the Russian army on the march in cold weather not only use no spirits, but no man who has lately taken any is allowed to march. The guides at Chamouni and the Oberland, when out in the winter, have invariably found spirits hurtful; they take only a little light wine (Forbes). The bathing men at Dieppe, who are much exposed to cold from long standing in the sea, also find that spirits are hurtful, and take only a little weak wine (Levy).

The reason of this is not difficult to find, when we remember the lessening of pulmonary carbonic acid, and the impairment of the chemical changes (correlated to heat and mechanical motion) which alcohol produces. The instances in which spirits are popularly supposed to be useful, are those in which hot water is taken with them, and the benefit is doubtless simply owing to the heat of the liquid.

Great Heat.—The evidence here also is almost equally conclusive against the use of spirits or beverages containing much alcohol. Dr Carpenter has assembled the most conclusive testimony from India, Brazil, Borneo, Africa, and Demerara. The best authorities on tropical diseases speak as strongly; Robert Jackson, Ranald Martin, Henry Marshall, and many others. It seems quite certain, also, that not only is heat less well borne, but that insolation is predisposed to.

* I have borrowed largely from Carpenter's admirable Essay on Temperance, and his other writings, and also from Spencer Thomson's useful work on the same subject, as well as from many other writers.

† He says (Adams' translation, 1807, vol. i. p. 219), "at first we imagined that drinking "strong liquors would diffuse a heat through the body, and consequently render it less sensible "of the painful sharpness of the cold; but to our surprise we felt no manner of strength in them, "nor were they any greater preventative against the cold than common water."

The common notion that some form of alcoholic beverage is necessary in tropical climates is, I firmly believe, a mischievous delusion. I brought to Dr Carpenter's notice the case of the 84th Regiment, in which I formerly served, which from the years 1842 to 1850, numbered many teetotallers (at one time more than 400) in its ranks; and the records of this regiment show that, both on common tropical service and on marches in India, the teetotallers were more healthy, more vigorous, and far better soldiers than those who did not abstain.* The experience of almost every hunter in India will be in accordance with this.

On this point the greatest army surgeons have spoken strongly (Jackson especially, and Martin); and yet nothing is more common, even at the present day, than to hear officers, both in India and the West Indies, assert that the climate requires alcohol. These are precisely the climates where alcohol is most hurtful.

With regard to service and exercise in the tropics, we have the strong testimony of Ranald Martin that warm tea is the best beverage; and this will be corroborated, I believe, by every one who has made long marches, or hunting excursions, in India, and has carefully observed what kind of diet best suited him.

It is, no doubt, in its opposition to the regressive metamorphosis, already probably interfered with by the high temperature, that we are to look for the cause of the pernicious effect of alcohol, when used under the influence of great heat. If the view, that the perspiration is lessened by alcohol, turns out to be correct, we have another cause for the hurtfulness of alcohol, as then the great agency by which the heat of the body is lowered, viz., surface evaporation, is lessened.

The Exposures and Exertions of War.—On this point, also, there is considerable unanimity of opinion. The greatest fatigues, both in hot and cold climates, have been well borne—have been, indeed, best borne by men who took no alcohol in any shape. The march, which Sir James M'Grigor says was made under fatigues as great as troops ever underwent in any war, viz., across the desert to join Sir Ralph Abercromby in Egypt, in 1804, was accomplished without spirits; and not only accomplished, but the troops "were remarkably healthy."

To cite a well-known individual instance of great exertion in a hot climate, Robert Jackson marched 118 miles in Jamaica, carrying a load equal to a soldier's, and decided that "the English soldier may be rendered capable of going through the severest military service in the West Indies; and that temperance will be one of the best means of enabling him to perform his duty with safety and effect. The use of ardent spirits is not necessary to enable a European to undergo the fatigue of marching in a climate whose mean temperature is from 73° to 80°. I have always found the strongest liquors the most enervating."

Even under circumstances when the use of spirits might be supposed *a priori* to be useful, as when men are exposed to cold and wet, soldiers are better without alcohol. On this point, no testimony can be stronger than that given by Inspector-General Sir John Hall, K.C.B.† He says:—

"My own opinion is, that neither spirit, wine, nor malt liquor, is necessary for health. The healthiest army I ever served with had not a single drop of any of them; and although it was

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* See "Carpenter's Physiology of Temperance" for full details. The officers, who by their example and precept, produced this great effect in a regiment in India, and proved that men are healthier and happier in India without any alcoholic beverage, were Lieut.-Colonel Willington, Captain (now Major-General) Russell, and Lieut. and Adjutant Seymour, an officer of the greatest promise, who died from dysentery, contracted during the mutiny.

† Medical History of the War in the Crimea, vol. i. p. 504.

exposed to all the hardships of Kaffir warfare at the Cape of Good Hope, in wet and inclement weather, without tents or shelter of any kind, the sick-list seldom exceeded one per cent.; and this continued not only throughout the whole of the active operations in the field during the campaign, but after the men were collected in standing camps at its termination; and this favourable state of things continued until the termination of the war. But immediately the men were again quartered in towns and fixed posts, where they had free access to spirits, an inferior species of brandy sold there, technically called 'Cape Smoke,' numerous complaints made their appearance among them.

"In Kaffraria the troops were so placed that they had no means of obtaining liquor of any kind; and all attempts of the 'Winklers' to infringe the police regulations were so summarily and heavily punished by fines and expulsion, that the illicit trade was effectually suppressed by Colonel Mackinnon, the Commandant of British Kaffraria; and the consequence was, that drunkenness, disease, crime, and insubordination were unknown; and yet that army was frequently placed in the very position that the advocates for the issue of spirits would have said required a dram.

"Small as the amount of sickness and mortality was in the Crimea, during the winter 1855–56, they would have been reduced one-half, I am quite sure, could the rule that was observed in Kafferland have been enforced there."

In the same Kaffir war (1852), a march was made by 200 men from Graham's Town to Bloomfronthein, and back; 1000 miles were covered in seventy-one days, or at the rate of nearly 15 miles daily; the men were almost naked, were exposed to great variations of temperature (excessive heat during day; while at night water froze in a bell-tent, with twenty-one men sleeping in it); and got as rations only biscuit (meat $1\frac{1}{2}$ ℔), and what game they could kill. For drink they had nothing but water. Yet this rapid and laborious march was not only performed easily, but the men were "more healthy than they had ever been before;" and after the first few days, ceased to care about spirits. No man was sick till the end of the march, when two men got dysentery, and these were the only two who had the chance of getting any liquor.*

To take an instance from a colder climate, and a more rigorous exposure, I will quote the opinion given by Dr Mann, one of the few American surgeons in the war of 1812–14, who have left any account of that contest.

Dr Mann says,†—"My opinion long has been that ardent spirits are an unnecessary part of a ration. Examples may be furnished to demonstrate that ardent spirits are a useless part of a soldier's ration. At those periods during the revolutionary war, when the army received no pay for their services, and possessed not the means to procure spirits, it was healthy. The 4th Massachusetts Regiment, at that eventful period of which I was the surgeon, lost in three years by sickness not more than five or six men. It was at a time when the army was destitute of money. During the winter 1779–80 there was only one occurrence of fever in the regiment, and that was a pneumonia of a mild form. It was observable in the last war, from December 1814 to April 1815, the soldiers at Plattsburgh were not attacked with fevers as they had been the preceding winters. The troops during this period were not paid—a fortunate circumstance to the army, arising from the want of funds. This embarrassment, which was considered a national calamity, proved a blessing to the soldier. When he is found poor in money, it is always the case that he abounds in health—a fact worth recording."

To take only one more instance. The 10th corps of the army of the Germanic Confederation, in the autumn of 1846, had 27,859 men under arms. Of these 21,752 received rations of spirits, and gave 472 sick, or 2·17 per cent.; 6107 received no spirits, and gave 79 sick, or 1·27 per cent.‡

Discipline, Temper, Cheerfulness, Endurance.—It is a fact known to every officer that good discipline is inversely as drunkenness; but it is not so well

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* This was related to me by one of the men who made the march—Corporal Paul of the 12th Regiment.

† Quoted by Hamilton, "Military Surgery," p. 61.

‡ Squillier, "Des Subsistances Militaires," p. 422.

known that, when debarred from spirits and fermented liquids, men are not only better behaved, but are far more cheerful, are less irritable, and endure better the hardships and perils of war. The courage and endurance of a drunkard are always lessened; but in a degree far short of drunkenness, spirits lower, while temperance raises, the boldness and cheerfulness of spirit which a true soldier should possess. This was remarkably shown by the "illustrious garrison" of Jellalabad, in the old Affghan war. Debarred from all alcoholic beverages, it was noticed by all that the men were not only healthier and better behaved, but were more hopeful and cheerful than could have been anticipated. Sir John Hall's experience is to the same effect; and there are many other instances. This is no unimportant matter for the combatant officer to consider; the spirit of the troops may make the difference between a success or a reverse. The experience of the late American civil war abounds in instances of the effects of the use or disuse of spirits. A surgeon of the United States army, after describing the improvement of discipline, says, "The curse of an army is intoxicating liquors; the spirit ration is the great source of all this mischief." In some of the American regiments spirit prohibition was enforced with the best results.*

Resistance to Disease.

Malaria.—There are instances both for and against the view that spirits are useful against malaria. On both sides the evidence is defective; but

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* The custom of giving rations of spirits to soldiers and sailors (even now not altogether discontinued), was one of those incredible mistakes which are only made worse by the explanation that it was done to please the men, and to cover neglect in other ways. If any one wishes to see what our army was in former days, and how our dreadful military regulations made men drunkards in spite of themselves, I may refer them to an old Peninsular surgeon's (William Fergusson's) Notes and Recollections of a Professional Life (1846). "During the last war" (he says, p. 74), "our sailors and soldiers appeared to live for the purpose of getting drunk; with them it seemed to be the chief article of their creed—the chief end of life. . . . . 'Grog, grog,' was still the cry; I have seen it, as it were, forced down the throats of the innocent negro boy and the uncorrupted young recruit. We seemed to believe that the term *aqua vitæ* was its true designation. Every one was to have it; no matter what the age, the colour, the country, or the breeding. Our Portugeese allies in the Peninsula were the soberest of mankind. They liked their own weak country wine to dilute their food, but that would not do for us. We actually sent for the rum of the West Indies and gave it them; and at the battle of Busaco, I saw a party of Portuguese artillery, as soon as the rum ration was served, as if they had been possessed by a devil (and they actually were possessed by a devil in the shape of alcohol), draw their swords and fight with one another, when actually under the fire of the enemy" (p. 85).

He cites numerous most lamentable facts, and well concludes that "our canteen system will in after times be viewed with horror and astonishment, at its folly, corruption, and wickedness."

I do not recall these opinions (and I might fill a chapter with similar expressions and almost incredible proof of the infatuation which formerly possessed us in this matter) without a motive. There is too much reason to fear that many officers still believe that soldiers must have spirits. Fergusson says, that "the exceeding vulgarity of the prejudice that ardent spirits impart strength and vigour to the human frame is disgraceful to educated men;" and yet this belief is still actually held by many persons in authority. Although in the army, drinking is the great source of all crime and insubordination; although even within the last twelve years we have had one if not more instances that, even during an assault, men will sacrifice anything, even their honour, to obtain spirits; although the best officers know that this is the one point on which they cannot depend on their men, far too little has been done to make our army temperate. I do not mean to say that nothing has been done; on the contrary, in this, as in all things, progress has been made, but the measures are not sufficient to control an evil so gigantic. It is the same thing in civil life; there is no question that more disease is, directly and indirectly, produced by drunkenness than by any other cause, and that the moral as well as the physical evils proceeding from it are beyond all reckoning; and yet the attempts made to secure a complete legislative consideration of the question are looked upon as the delusions of fanatics, and are opposed with a bitterness which could only be justified if the degradation and not the improvement of mankind was desired. To see a Royal Commission issued to determine how clergymen should be dressed, and if candles should burn on an altar, while the national canker of drunkenness and its accompanying crimes is neglected, is indeed to take "tithes of anise and cummin, and to neglect the weightier matters of the law."

there are so many cases in which persons have been attacked with malarious disease who took spirits, that it is impossible to consider the preventive powers great, even if they exist at all. On the other hand, when teetotallers have escaped malaria (as in the instance recorded by Drake),* there have been other circumstances, such as more abundant food and better lodging, which will explain their exemption. The probability is, that the reception and action of malaria is not influenced by the presence or absence of alcohol in the blood, unless the amount of alcohol is so great as to lessen the amount of food taken.

Yellow Fever.—It is a general opinion in New Orleans and Mobile that the victims of yellow fever are chiefly those who drink freely (Drake). The old West Indian experience is to the same effect.

Cholera.—Intemperance, *per se*, has no influence, and teetotalism does not guard against cholera. When a regiment is attacked with cholera, and the men take to drinking, a number of pseudo-cases come into hospital of vomiting and cramps, which are often returned as cholera, but I believe they seldom if ever pass into true cholera.

Dysentery.—It has been supposed, from some statistics for 1847, published in the "Fort George Gazette," that teetotallers were more subject to dysentery, but the error was committed of not estimating sufficiently the influence of a particular station (Secunderabad), where it so happened a number of teetotallers were stationed during an outbreak of dysentery. The conditions of the station were to blame, not the habits of the men.

Looking back to this evidence, it may be asked, Are there any circumstances of the soldier's life in which the issue of spirits is advisable, and if the question at any time lies between the issue of spirits and total abstinence, which is the best?

To me there seems but one answer. If spirits neither give strength to the body, nor sustain it against disease—are not protective against cold and wet, and aggravate rather than mitigate the effects of heat—if their use even in moderation increases crime, injures discipline, and impairs hope and cheerfulness—if the severest trials of war have been not merely borne, but most easily borne, without them—if there is no evidence that they are protective against malaria or other diseases—then I conceive the medical officer will not be justified in sanctioning their issue under any circumstances.†

The terrible system which in the East and West Indies made men drunkards in spite of themselves, and which by the issue of the morning dram did more than anything else to shatter the constitutions of the young soldiers, is now becoming a thing of the past. But the soldier is still permitted to get spirits too easily, and is too ignorant of their fatal influence on his health.‡ Still the British army bears the unhappy character of the most intemperate army in Europe, and it is certain that its moments of misconduct and misfortune have been too frequently caused by the unrestrainable passion for drink. Remembering all these things, and how certainly it has been proved that

* On the Interior Valley of North America.

† Yet so inveterate is the tendency to order spirits, that when great efforts were made, and would have been continued to be made, to supply beer to the troops during the Crimean War, medical officers were found to advise Lord Raglan to substitute rum for beer.

‡ I noticed in a Sanitary Report from Newera Ellia, in Ceylon (in 1860), that invalids who are sent to that sanitarium are permitted to purchase spirits cheaply and without restriction. What is the use of sending men to hill climates, and then at once neutralising the benefit by such a regulation as this, as if the mere change of climate would do all, and sanitary regulations and ordinary prudence were quite unnecessary? Lord Strathnairn issued an order in 1864, reducing the spirit ration in India to one-half. He made many improvements; this was one of his greatest.

drunkenness increases the spread of syphilis, it is not too much to say that the repression of this vice must be considered to be one of the chief duties of every officer in the army. Moderation should be encouraged by precept and example; wholesome beer and light wine should be invariably substituted for spirits, and if these cannot be procured, then it may safely be said that the use of tea, coffee, or simple water, is infinitely preferable to spirits under all circumstances of the soldier's life.

SECTION II.

NON-ALCOHOLIC BEVERAGES.

Sub-Section I.—Coffee.

Composition.

	In 100 Parts (Payen).
Water,	12
Cellulose,	34
Fatty substances,	10 to 13
Sugar, dextrin, Undetermined vegetable acid,	15·5
Legumen,	10
Nitrogenous substance,	3
Coffee-gallate of potash, and caffein,*	3·5 to 5
Free caffein,	·8
Insoluble solid oil,	·001
Aromatic oil,	·002
Mineral substances—Potash, magnesia, lime, phosphoric acid, chlorine,	6·679

In the salts the potash is in largest amount. The total amount of caffein (free and combined), according to Payen, would be about 1·736 per cent.; but this is more than other observers have found it (1·31 per cent.) In roasted coffee berries the average of Boutron and Robiquet's analyses gives ·238 per cent. of caffein.

When coffee is roasted it swells, but becomes lighter (15 to even 25 per cent. if the coffee is dark-roasted). The sugar is changed into caramel, the peculiar aroma is developed, the union between the caffein and the coffee-gallic acid is broken up; several gases are formed, viz., carbonic acid (in greatest amount), carbonic oxide, and nitrogen. It is owing to these gases that the roasted coffee swells so much (Coulier, *Recueil de Mémoires de Méd. Mil.* Juin 1864, p. 508). The temperature in roasting should not be higher than 320° Fahr.

As an article of diet, coffee stimulates the nervous system, and in large doses produces tremors. It increases the force and frequency of the pulse, and removes the sensation of commencing fatigue during exercise. It has been said (J. Lehmann and others) to lessen the amount of urea and phosphoric acid, but this is doubtful.† It appears, however, to increase the

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* Payen calls the acid chloroginic, but I have used the term employed by Rochleder.

† While Hoppe found a decrease in dogs, Voit found no alteration of urea; and some very careful experiments made by Mr Squarey of University College do not confirm Lehmann's observations on men so far as the urea is concerned. Mr Squarey's experiments are far more complete than those of Lehmann; the urea was not affected even by very large quantities of coffee. It would be interesting to examine the urine again after the use of the *Erythroxylon coca*. The late work of M. Moreno of Maiz (Paris, 1868), confirms the previous statements of the removal of the sensation of hunger. The cold infusion increases, he affirms, the arterial tension.

urinary water. The pulmonary carbonic acid is said to be increased (E. Smith). It increases the action of the skin.

Coffee is a most important article of diet for soldiers, as not only is it invigorating, without producing subsequent collapse, but the hot infusion is almost equally serviceable against both cold and heat: in the one case, the warmth of the infusion—in the other, the action on the skin, being useful, while in both cases the nervous stimulation is very desirable. Dr Hooker tells us that in the antarctic expedition the men all preferred coffee to spirits, and this was the case in the Schleswig-Holstein war of 1849.

Fig. 62.—Testa of raw Coffee × 170; the right-hand figure shows the double spiral fibres in the raphe of the berry × 500.

The experience of Algeria and India (where coffee is coming more and more into use) proves its use in hot climates.

But there is another recommendation; it has been asserted to be protective against malaria. The evidence, certainly, is not strong, but still is sufficient to authorise its large use in malarious districts.

Making of Coffee.—But the use of coffee can never be fully obtained unless the infusion is well made, and it should not be beneath the dignity of the medical officer to attend to the making of coffee for troops.

Roasted and ground coffee must be served out to troops, as the delicate operation of roasting can never be performed by soldiers. Exposed to the air, the roasted and ground coffee loses its aroma in from two to four months; but if packed in tins it will keep it for several months. The tins should not be too large, so that no more than necessary may be exposed to the air. It has been said that the tin is acted upon, but this does not appear to be the case for some time.

The coffee must not be boiled, or the aroma is in part dissipated; but if

made with water of 180° or 200°, the coffee only gives up 19 to 25 per cent., whereas it ought to yield 30 to 35 per cent. The amount, however, depends also on the kind and degree of roasting. In order to get the full benefit of the coffee, therefore, after the infusion has been poured off, the grounds should be well boiled in some more water, and the hot decoction poured over fresh coffee, so that it may take up aroma; the coffee thus partially exhausted can be used on the next occasion for boiling.

Fig. 63.—Raw Coffee-berry; transverse section × 170.

To clear the coffee some cold water should be poured in from a little height; the cold water sinks through the coffee, and carries down the suspended particles. The infusion of coffee has a specific gravity of about 1008 to 1010; the oil, caffein, sugar, dextrin, and mineral matters, are taken up by water.

Choice of Coffee.—This is determined entirely by the aroma and taste of the roasted coffee and of the infusion. If the coffee has been damaged (as by sea-water, when the berries are washed in fresh water and redried), there

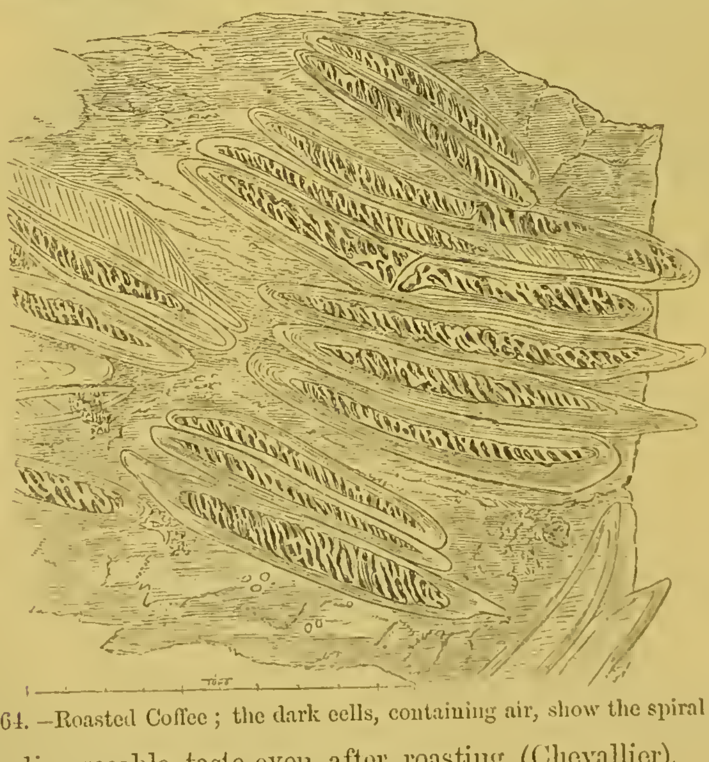

Fig. 64.—Roasted Coffee; the dark cells, containing air, show the spiral fibre.

is always a disagreeable taste even after roasting (Chevallier). The berries give up less than usual to water (12 per cent.)

Adulterations.—The microscope detects adulterations with the greatest facility.

The structure of the coffee-berry is shown in the drawings.

The long cells of the testa (figs. 62 and 64) are very marked. The interior of the berry also presents characters which are quite evident; an irregular areolar tissue contains light or dark yellow angular masses and oil globules, which are very different from any adulterations. The little cork-screw-like unrolled spiral fibres are chiefly found in the bottom of the raphe. The usual adulterations of coffee are roasted chicory;* cereal grains or beans, potatoes, and sugar.

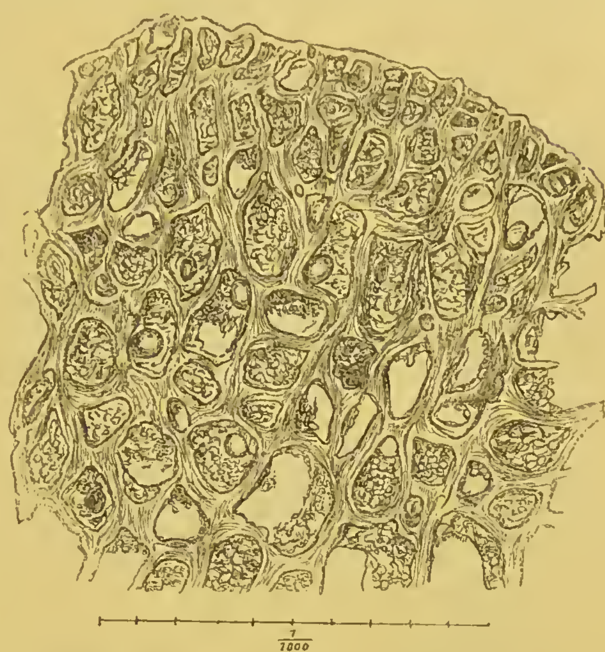

Fig. 65.—Roasted Coffee-berry; transverse section.

1. Chicory is discovered by its smell; by yielding a darker and denser infusion of a specific gravity of 1018 to 1020; and by its microscopic characters. It also sinks in water when roasted, whereas coffee floats in consequence of the development of gas during roasting; but this is not a very good test, as coffee also sinks at last. The microscopic test is the most important,

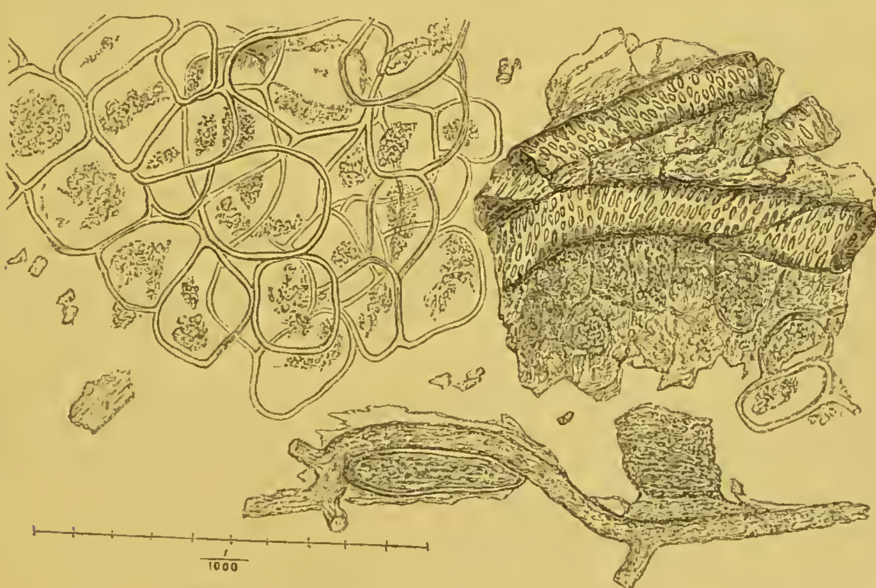

Fig. 66.—Chicory root; cells and dotted ducts.

and both the cells and dotted ducts of chicory are quite characteristic, at least nothing like them exists in coffee.

2. Roasted corn or beans are at once known by the starch-grains, which

* Chicory is itself adulterated with roasted barley and wheat grain, acorns, mangold wurzel, saw-dust, and beans and peas.

frequently preserve the precise character of wheat or barley or beans. (See figures of these grains, p. 204 *et seq.*) Iodine turns them at once blue. The infusion also gives a blue with iodine.

3. Potato starch is also at once detected; there is nothing like it in coffee. (See figure, p. 208.)

4. Sugar is detected by solution, and by the copper solution which it reduces, as the kind of sugar is almost always glucose. If caramel or burnt sugar be present, make an infusion, evaporate, dry, and taste; if the extract be brittle, dark coloured, and bitter to the taste, caramel has been added (Hassall).

5. Pereira* has given a long list of adulterations of chicory, and Hassall has also detected mixture with mangold-wurzel, parsnip, carrot, acorn, and saw-dust. The cells of mangold-wurzel are like chicory, but much larger; those of carrot and parsnip are something like chicory, but contain starch-cells; the starch-grains of the acorn are round or oval, with a deep culvert depression or hilum.

Sub-Section II.—Tea.

The chief kinds of black tea are Souchong, Congou, Oolong, and Pekoe. Bohea is not now found in the market. The chief green teas are Hyson, Hyson-stem, Twankay, Caper, and Gunpowder.

Composition of Black Tea.†	Per cent. Dry tea.	Moist tea.
Thein,	1·778	1·576
Albumin,	2·680	2·375
Dextrin,	9·780	8·668
Cellulose,	22·650	20·077
Wax,	·150	·130
Chlorophyll,	2·145	1·901
Resin,	2·486	2·203
Tannic acid,	15·760	13·969
Æthcrial oil,	·755	·669
Extractive matters,	20·770	18·410
Apothema,	·780	·690
Ash,	5·425	4·808
Water,	...	6·5

The ash consists principally of potash, soda, magnesia, phosphoric acid, chlorine, carbonic acid, iron, and silica.

There is rather more tannic acid, and more thein and ætherial oil, in green than black tea, and less cellulose; otherwise the composition is much the same (Mulder).

In some good teas the amount of thein is much greater. Péligot found as much as 6·21 per cent. in dry tea. The thein is combined with tannic acid.

Black tea contains from 6 to 10 per cent. of water—more often the latter quantity; green tea about 8 per cent.

Black tea yields to boiling water,		29–45 per cent.
	As a mean,	38 ,,
Green ,, ,, ,,		40–48 ,,
	As a mean,	43 ,,

About $\frac{6}{7}$ths of the soluble matters are taken up by the first infusion with hot water.

If water contain much lime or iron, it will not make good tea; in each

* Materia Medica, vol. ii. p. 1578 (1863).
† Mean of analyses by Mulder, Warrington, Stenhouse, and Péligot. Taken from Moleschott.

Leaves and stalks of best Tea brought from China 1861, by private hand natural size.
Generally in Commercial Tea the leaves are much larger & thicker, & often are cut transverly into two or three parts Some stalks & remains of flowers are found in all Tea even the best.

LEAVES USED IN THE ADULTERATION OF TEA

The Sloe, Willow, Oak, Beech, Elder, and Hawthorn have been nature-printed & then Lithographed. The Drawings of the Chloranthus Inconspicuus and the Camelia Sasanqua which are said to be used by the Chinese are copied from Hassall The Leaves of the Elm Poplar Plane are said to be sometimes used in England. Falsification with any kind of leaf is however now decidedly uncommon in this country

case the water should be well boiled with a little carbonate of soda for 15 or 20 minutes, and then poured on the leaves.

In the infusion are found dextrin, glucose, tannin, and thein. About 47 per cent. of the nitrogenous substances pass into the infusion, and 53 per cent. remain undissolved. If soda is added, a still greater amount is given to water.

The green tea is either natural or coloured (faced) with indigo, Prussian blue, clay, carbonate and acetate of copper, curcuma, gypsum, and chalk.

Scraping the tea-leaves and microscopic examination at once detect the shining blue particles of indigo and Prussian blue; and the addition of an acid indicates which is indigo.* Copper is at once detected by solution in an acid and addition of ammonia.

As an Article of Diet.—Tea seems to have a decidedly stimulative and restorative action on the nervous system, which is perhaps aided by the warmth of the infusion. No depression follows this. The pulse is a little quickened. The amount of pulmonary carbonic acid is, according to E. Smith, increased.† The action of the skin is increased; that of the bowels lessened. The kidney excretion is little affected; perhaps the urea is a little lessened, but this is uncertain.‡

As an article of diet for soldiers, tea is most useful. The hot infusion, like that of coffee, is potent both against heat and cold; is most useful in great fatigue, especially in hot climates (Ranald Martin); and also has a great purifying effect on water. Tea is so light, is so easily carried, and the infusion is so readily made, that it should form the drink *par excellence* of the soldier on service. There is also a belief that it lessens the susceptibility to malaria, but the evidence on this point is imperfect.

Choice of Tea.—The tea should not be too much broken up, or mixed with dirt. Spread out, the leaves should not be all large, thick, dark, and old, but some should be small and young. There will always be in the best tea a good deal of stalk and some remains of the flower. In old tea much of the ætherial oil evaporates, and the aroma is less marked.

The infusion should be fragrant to smell, not harsh and bitter to taste, and not too dark. The buyers of tea seem especially to depend on the smell and taste of the infusion.

Structure of the Tea Leaf.—The border is serrated nearly, but not quite to the stalk; the primary veins run out from the midrib nearly to the border, and then turn in, so that a distinct space is left between them and the border. The leaf may vary in point of size and shape, being sometimes broader, and sometimes long and narrow. The appearance under the microscope of the upper and under surfaces is seen in the drawing. The border and the primary venation distinguish it from all leaves. The leaves which it is said have been mixed with or substituted for tea in this country are the willow, sloe, oak, Valonia oak, plane, beech, elm, poplar, hawthorn, and chestnut; and in China, *Chloranthus inconspicuus*, *Camellia Sasanqua*, are said to be used. Of these the willow and the sloe are the only leaves which at all resemble tea leaves. The willow is more irregularly, and the sloe is much less perfectly and uniformly serated.

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* The brick tea of the Tartars consists of old tea leaves, mixed with the leaves and stems of *Rhamnus theèzans*, *Rhododendron*, *Chrysanthemum*, *Rosa canina*, and other plants, mixed with ox's or sheep's blood. It is much used to purify water.

† Phil. Transactions, 1859.

‡ The evidence with respect to the urine is very contradictory; but, on the whole, the action seems to be inconsiderable. Dr Edward Smith considers that "tea promotes all vital actions, and increases the action of the skin." It is, perhaps, impossible at present to express its action in so succinct a form.

To examine the leaves, make an infusion, and then spread out a number of leaves; if a leaf be placed on a glass slide, and covered with a thin glass, and then held up to the light, the border and venation can usually be well seen.

The leaves of the Valonia, if used, are at once detected by acicular crystals being found under the microscope.

Sometimes exhausted tea leaves are mixed with catechu or with a coarse powder of a reddish-brown colour, consisting chiefly of powdered catechu, and called "La Veno Beno." Gum and starch are added, the leaves being steeped in a strong solution of gum, which, in drying, contracts them. The want of aroma, and the collection at the bottom of the infusion of powdered catechu, or the detection of particles of catechu, will at once indicate this falsification, which is, however, very uncommon.

Extraction of Thein.

Occasionally it may be desired to determine the quantity of thein. Take 100 grains of tea, exhaust with boiling water, and add solution of subacetate

Fig. 67.—Black Dried Tea Leaf.

of lead; filter; pass hydrosulphuric acid, to get rid of excess of lead; filter; evaporate to small bulk, and add a little ammonia; add more water, decolorise with animal charcoal, and evaporate slowly to small bulk. White feathery crystals of thein form, which should be collected on filtering paper, dried at a very low heat, and weighed.

Determination of Tannin.

Make an infusion, and add solution of gelatine; collect precipitate, dry and weigh—100 grains = 40 of tannin (Marcet).

Examination of Tea.

Judge of the aroma of the dry tea and infusion; taste infusion; spread out leaves and see their characters; collect anything like mineral powder, and examine under microscope.

In making the infusion, take 100 grains of tea to 5 ounces of boiling distilled or rain water, so as always to have the infusion of the same strength. Dry and weigh the exhausted tea leaves, and calculate the percentage of soluble matter. If desired, determine the thein and tannin.

Sub-Section III.—Cocoa.

Composition.—Although the theobromin of cocoa is now known to be identical with thein and caffein, the composition of cocoa removes it widely from tea and coffee. The quantity of fat varies even in the same sort of cocoa: it is usually from 45 to 49 per cent.; the theobromin is 1·2 to 1·5 per cent.; the protein substances 13 or 18 per cent. The ash contains a large quantity of phosphate of potash.

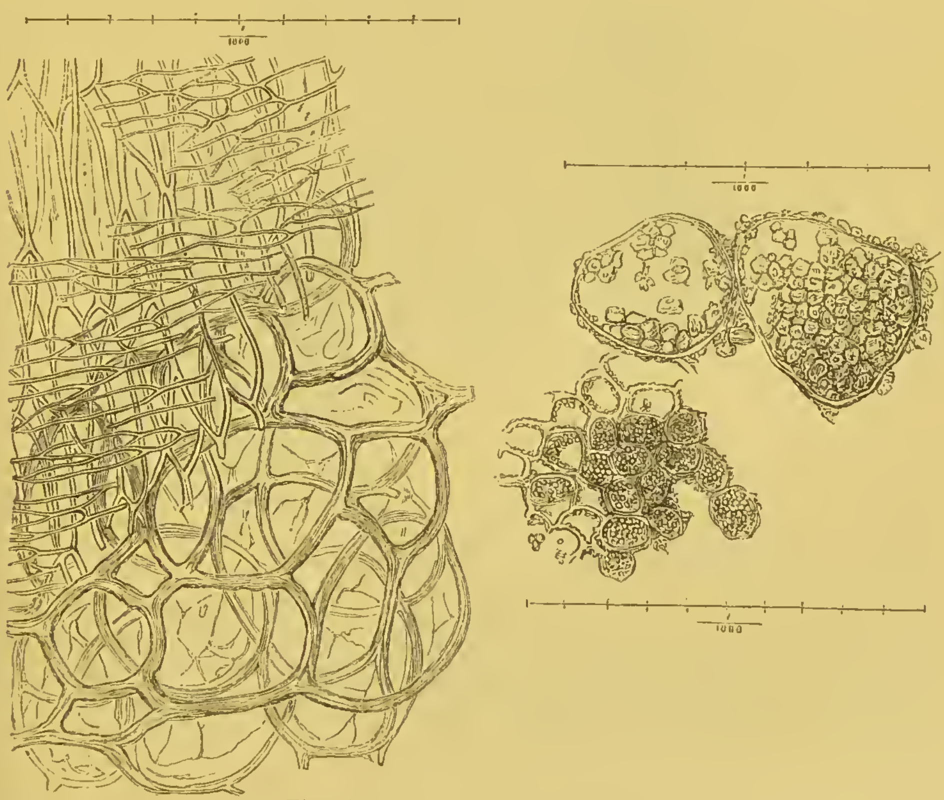

Fig. 68.—Cocoa, Outer Coat × 190.

As an Article of Diet.—The large quantity of fat and albuminoid substance makes it a very nourishing article of diet; and it is therefore useful in weak states of the system, and for healthy men under circumstances of great exertion. It has been even compared to milk. In South America cocoa

and maize cakes are used by travellers; and the large amount of agreeable nourishment in small bulk enables several days' supplies to be easily carried (Humboldt).

By roasting, the starch is changed into dextrin; the amount of margaric acid increases, and an empyreumatic aromatic substance is formed.

The changes depend on the amount of roasting; the lighter-coloured nuts contain more unchanged fat, and less aroma; the strongly roasted and dark cocoas have more aroma and bitterness.

Choice and Adulterations.—In commerce, cereal grain, starches, arrowroot, sago, or potato starch and sugar, are very commonly mixed with cocoa; and some of the so-called homœopathic cocoas are rightly named, for the amount of cocoa is very small. Brick-dust and peroxide of iron are sometimes used (Normandy).* The structure of the cocoa is very marked.

Fig. 69.—Cocoa, Under Parts, Middle Coat × 190.

The starch-grains of cocoa are small, and embedded usually in the cells. The presence of starch-grains of cereals, arrowroot, sago, or other kinds of starch, is at once detected by the microscope (see figures *ante* of these starches). Sugar can be detected by the taste, and by solution. Mineral substances are best detected by incineration, digesting in an acid, and testing for iron, lead, &c.

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* Hassall examined 54 samples; 8 were genuine, 43 contained sugar, and 46 starch; 39 out of 68 samples contained earthy colouring matter, as reddle, Venetian red, and umber (On Adulteration, p. 169).

SECTION III.

CONDIMENTS.

SUB-SECTION I.—VINEGAR.

As an Article of Diet.—Robert Jackson was of opinion that the use of vinegar was too restricted in the army. This opinion he appears to have formed from considering the great use of vinegar made by the Romans. Whatever may have been the source of the opinion, there is no doubt of its correctness. Acetic acid plays that double part in the body which seems so important, of first an acid of a neutral salt, and then, in the form of carbonic acid, as the acid of an alkaline salt. But this valuable dietetic quality is partly counterbalanced in English vinegar by the unfortunate circumstance that sulphuric acid ($\frac{1}{1000}$th part by weight) is allowed to be added to vinegar, and thus a strong acid is taken into the body, which is not only not useful in nutrition, but which is hurtful, from the tendency to form insoluble salts of lime. As the addition of sulphuric acid is not necessary, and, indeed, is not permitted on the Continent, it is to be hoped the Legislature will soon alter a system which has the effect only of injuring an important article of diet. The amount of vinegar which may be used may be from one to several ounces. On marches, the Romans mixed it with water as a beverage.

Examination of Vinegar.—Several kinds of vinegar are in the market, known by the Nos. 16, 18, 20, 22, 24. Nos. 22 and 24 are the best, and contain about 5 per cent. of pure acetic acid. The weakest kinds contain less than 3 per cent.

Examination.

Quality.—1. Take specific gravity of the best, 1022; of the worst, 1015. If below this, water has been added.

2. Determine acidity of 100 grains, or of 10 C.C., with the alkaline solution (see Beer).

The acidity of English vinegar is chiefly caused by acetic and sulphuric acids; but it is usually calculated at once as dry acetic acid. If it falls below 3 per cent., water has probably been added. (The lowest noted by Hassall in 33 samples was 2·29.)

If the specific gravity be low, and the acidity high, excess of sulphuric acid may have been added.

If the alkaline solution cannot be prepared, the acidity must be determined with dried or crystallised carbonate of soda. Weigh 100 grains of dried sodium carbonate, and add portions carefully to a weighed quantity of vinegar (100 grains, or 10 grammes), till it is neutralised; then weigh the remaining carbonate of soda, and calculate according to the atomic weights ($53 : 51 :: a : x$), or multiply the quantity used by ·962; the result is the amount of anhydrous acetic acid in the quantity of vinegar experimented upon.

In adding carbonate of soda to *wine* vinegar, the colour becomes dark and inky. Ammonia also gives a purplish precipitate in *wine*, but not in malt vinegar.

3. If excess of sulphuric acid be suspected, it must be determined by baryta; this requires care, as sulphates may be introduced in the water. Hydrochloric acid and barium chloride are added; the sulphate of baryta collected, dried, weighed, and multiplied by ·34305.

Adulterations.—Water; sulphuric acid in excess (see *ante*); hydrochloric acid (uncommon); or common salt (detected by nitrate of silver and dilute nitric acid); pyroligneous acid (distil and re-distil the distillate, the residue

will have the smell of pyroligneous acid); lead; copper from vessels (evaporate to dryness, incinerate, dissolve in weak nitric acid, divide into two parts, pass SH through one, and test for copper in the other by ammonia, or by a piece of iron wire); corrosive sublimate (pass SH, collect precipitate); capsicum, pellitory, or other pungent substances (evaporate nearly to dryness, and taste if the extract is hot and pungent); burnt sugar (evaporate to dryness, dissolve in boiling alcohol, evaporate to syrup, taste; burnt sugar gives a bitter taste and a dark colour to the syrup).

The presence of copper in the vinegar used for pickles may be easily detected by simply inserting the bright blade of a steel knife.

Sub-Section II.—Mustard.

Good mustard is known by the sharp acrid smell and taste. It is adulterated with turmeric (detected by microscope and liquor potassæ), wheat or

Fig. 70.—White Mustard Seed.—Cuticle consisting of a perforated cellular epiderm and mucilage cells, some by expansion escaping through the cuticular openings after being placed in water.

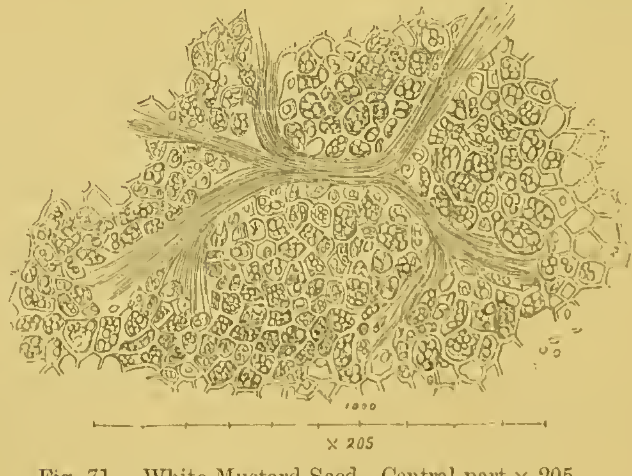

Fig. 71.—White Mustard Seed—Central part × 205.

barley starch (detected by microscope and iodine), and linseed (detected by

microscope). Every sample of mustard is at present mixed with turmeric and starch of some kind. Clay and plaster of Paris are sometimes added, and cayenne is added to bring up the sharpness, if much flour is used.

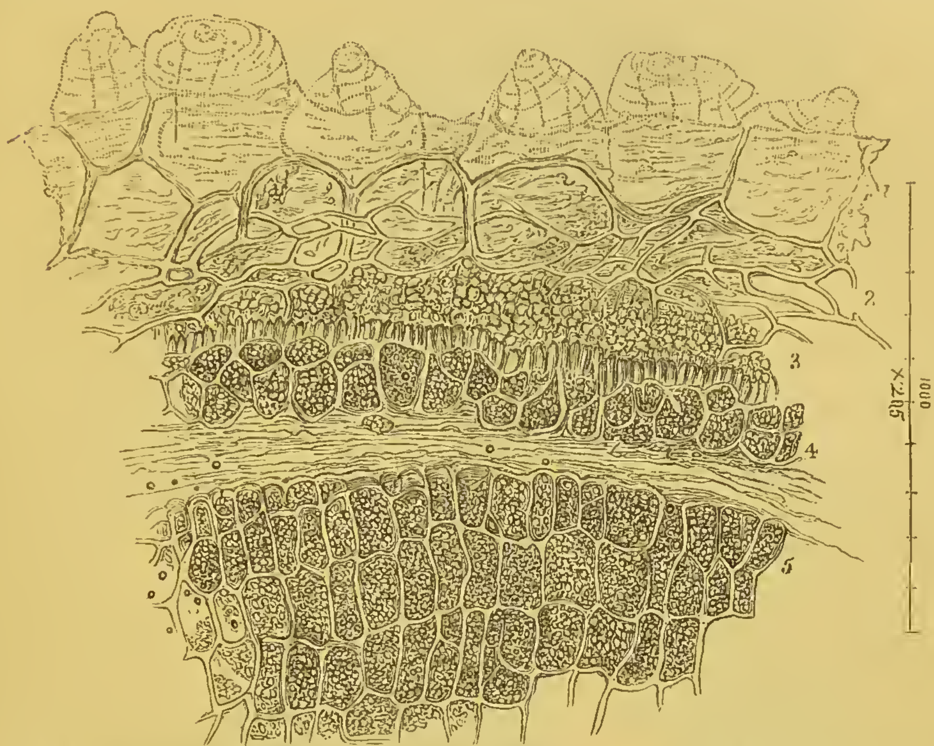

Fig. 72.—White Mustard Seed.—1. Outer coat, cuticle mucilage cells; 2. Fibrous recticular; 3. Small angular cells; 4. Large cells and very delicate membrane; 5. Interior of seed with a few minute oil globules.

The microscopic characters of mustard are well marked. The outer coat of the white mustard consists of a stratum of hexagonal cells, perforated in the centre, and other cells which occupy the centre portion of the hexagonal cells, and escape through the opening when swollen from imbibition of water; these cells are believed to contain the mucilage which is obtained when mustard is placed in water. There are two internal coats made up of small angular cells; the structure of the seed consists of numerous cells containing oil, but no starch. The black mustard has the same characters, without the infundibuliform cells.

Sub-Section III.—Pepper.

Pepper is adulterated with linseed, mustard husks, wheat and pea flour, rape cake, and ground rice. The microscope at once detects these adulterations.

The microscopic characters of pepper are rather complicated; there is a husk composed of four or five layers of cells and a central part. The cortex has externally elongated cells, placed vertically, and provided with a central cavity, from which lines radiate towards the circumference; then come some strata of angular cells, which, towards the interior, are larger and filled with oil. The third layer is composed of woody fibre and spiral cells. The fourth layer is made up of large cells, which towards the interior become smaller and of a deep red colour; they contain most of the essential oil of the pepper. The central part of the berry is composed of large angular cells, about twice as long as broad. Steeped in water, some of these cells become yellow, others

remain colourless. It has been supposed that the yellow cells contain peperine,

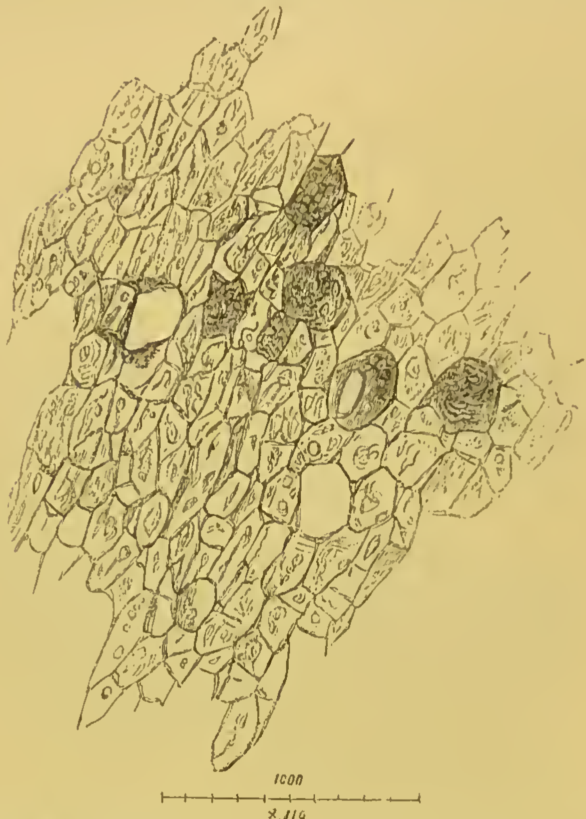

Fig. 73.—Black Pepper Berry.—Between centre and cortex.

Fig. 74.—Section of Black Pepper Berry (central portion).

as they give the same reactions as peperine does; the tint, namely, is deepened by alcohol and nitric acid, and sulphuric acid applied to a dry section causes a reddish hue (Hassall).

Fig. 75.—Transverse Section of Black Pepper Berry.

White pepper is the central part of the seed, but some small particles of cortex are usually mixed with it. It is composed of cells containing very small starch-grains. Hassall says that the central white cells are so hard they they may be mistaken for particles of sand. A little care would avoid this. The starch-grains are easily detected, however small, by iodine.

Pepper dust is merely the sweepings of the warehouses. Rape or linseed cake, cayenne and mustard husks, are mixed with pepper dust, and it is then sold as pepper.

Sub-Section IV.—Salt.

The goodness of salt is known by its whiteness, fine crystalline character, dryness, complete and clear solution in water. The coarser kinds, containing often chloride of magnesium, and, perhaps, lime salts, are darker coloured, more or less deliquescent, and either not thoroughly crystallised or in too large crystals.

SECTION IV.

LEMON AND LIME JUICE.

These juices contain free acids in large quantities, chiefly citric, and a little malic acid, sugar, vegetable albumen, and mucus.

The expressed juice of the ripe fruit of the *Citrus Limonum*, as ordered by the British Pharmacopœia, is said to have a specific gravity of 1·039, and to contain on an average 32·5 grains of citric acid in one fluid ounce.* The fresh juice of the lime (*Citrus Limetta*, or *Citrus acida*) has a rather less specific gravity (1·037), and contains less acid (32·22 grains per ounce).†

The late very important Merchant Shipping Act,‡ which regulates the issue of lemon juice on board merchant vessels, does not define the strength; but it has been stated by Mr Stoddart§ that the Board of Trade standard is a specific gravity of 1030 without spirit, and 30 grains of citric acid per ounce.

As found in commerce, for merchant shipping, or used in the Royal Navy, the lime or lemon juice is chiefly prepared in Sicily, or in the West Indies; it is mixed with spirit (usually brandy or whisky, which gives it a slightly greenish-yellow hue), and olive oil is poured on the top.

Sugar is added to it when issued, to make it more agreeable to taste, in the proportion of half its weight. Lemon juice is usually issued in bottles containing three to four pints, not quite filled, and is covered with a lair of olive oil. About 1 ounce of brandy is added to each 10 ounces of juice. Sometimes the juice is boiled, and no brandy is added; the former kind keeps best (Armstrong). Both are equal in anti-scorbutic power (Armstrong). Good lemon juice will keep for some years, at least three years (Armstrong); bad juice soon becomes turbid, and then stringy and mucilaginous, and the citric and malic acids decompose, glucose and carbonic acid being formed. Some turbidity and precipitate do not, however, destroy its powers.

As found in the market, it is frequently mixed with water, and sometimes with other acids. In 20 samples examined in 1868 by Mr Stoddart, 7 were genuine, 5 were watered, and 8 were artificial; tartaric acid being present in one, and sulphuric acid in another sample.

I have examined two good specimens of the Royal Navy lemon juice from Sicily with the following results:—When evaporated carefully down, after separation of the oil, it formed a brownish fragrant mass, which was dried with some difficulty, but was afterwards completely soluble in water. (If the operation is carried too far the extract decomposes, and then forms, according to Mr Stoddart, acetone, carbonic acid, and carbonic oxide and pyrocitric acid.) The look and smell of this extract was very characteristic of true lemon juice. The amount in my two samples was 7·186 and 7·1828 per cent. (Mr Stoddart's experiments give a rather less amount, viz. 6·17). When incinerated an alkaline whitish-grey ash was left; and if the alkalinity was neutralised by a standard acid, it corresponded to ·15 grains of citric acid per cent. The ash was ·52 and ·53 per cent. respectively, and of this ·38 were soluble salts; the potash was ·12 per cent., or just ½ grain per ounce, and the phosphoric acid was ·008 per cent., or ·035 grains per ounce.‖ The total acidity (= citric acid $C_6H_8O_7$) was 4·61 and 5·36 per cent., or on an average nearly 22 grains of citric acid ($C_6H_8O_7$) per ounce.

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* Mr Stoddart (Pharm. Jour., Oct. 1868) points out that the specific gravity is too high for the quantity of acid stated; there may, however, be other ingredients. He gives himself the specific gravity as 1·040 to 1·045, and the citric acid as 39 to 46 grains per ounce (citric acid $C_6H_8O_7$). Mr Stoddart mentioned that when lemons are kept the citric acid decomposes, and glucose and carbonic acid arises. But yet citric acid is made from damaged fruit.

† Stoddart, *op. cit.* p. 205.

‡ The Merchant Shipping Act, 1867. Mr Harry Leach, who superintends the part of the Act relating to lemon juice, has arranged a very good scheme of examination, which is being carried out by himself and by inspectors at the various ports.

§ Pharm. Jour. Oct. 1868, p. 204.

‖ The quantity of potash agrees closely with Mr Stoddart's statement, who found ·3 grains per ounce. Witt's analysis give from ·2 to ·5 per cent. of ash, of which 44·3 per cent. was potash, so that if the ash was ·5, the potash would be ·21 per cent., or ·9 grains in 1 ounce. It

This was below the Board of Trade's standard. The alcohol was 5 per cent., corresponding to 10 per cent. of brandy added.

In the examination the points which seem to me of consequence, in addition to the determination of the free acidity, are the fragrancy of the extract and the alkalinity of the ash, proving the existence of some alkaline citrate. This could, however, be imitated, but the fragrancy cannot be so.

Examination of Lemon Juice.

1. Pour into a glass and mark physical characters; turbidity, precipitate, stringiness, &c. The taste should be pleasant, acid, but not bitter. Add lime water, and boil; if free citric acid is present, a large precipitate of calcium nitrate is formed, which redissolves as the solution cools. Evaporate very carefully to extract, to test the fragrancy, &c.

2. Take the specific gravity, remembering that spirit is present; then, if necessary, evaporate to one half to drive off alcohol, dilute to former amount, and take specific gravity at 60° Fahr.

3. Determine acidity by alkaline solution as given at page 252. Express the acidity as citric acid ($C_6H_8O_7$); 1 C.C. of the alkaline solution = ·0192 of citric acid; but as it is tribasic the co-efficient ·0064 should be used, or the amount of alkaline solution must be divided by 3. As the acidity is considerable, the best way is to take 10 C.C. of the juice, add 90 C.C. of water, and take 10 C.C. of the dilute fluid, which will give the acidity of 1 C.C. of the undiluted juice. If the number of C.C. used is multiplied by ·28, it gives the acidity in grains per ounce.

4. Test for adulteration, viz.—

(*a.*) *Tartaric Acid.*—Dilute and filter, if the lime juice be turbid; add a little solution of acetate of potash; stir well, without touching the sides of the glass, and leave for twenty-four hours; if tartaric acid be present the bitartrate of potash will fall.

(*b.*) *Sulphuric Acid.*—Add barium chloride after filtration, if necessary; if any precipitates fall, add a little water and a few drops of dilute hydrochloric acid to dissolve the barium citrate, which sometimes causes a turbidity.

(*c.*) *Hydrochloric Acid.*—Test with silver nitrate and a few drops of dilute nitric acid.

(*d.*) *Nitric Acid.*—This is an uncommon adulteration; the iron or brucine test can be used, as in this case of water.

Factitious Lemon Juice.

It is not easy to distinguish well-made factitious lemon juice; about 552 grains of crystallised citric acid are dissolved in a wine pint of water, which is flavoured with essence of lemon dissolved in spirits. This corresponds to about 19 or 20 grains of dry citric acid per ounce. The flavour is not, however, like that of the real juice, and the taste is sharper. Evaporation detects the falsification.

Use of Lemon Juice.

In military transports, the daily issue of one ounce of lemon juice per head is commenced when the troops have been ten days at sea, and by the Mer-

is therefore certain that the utility of lemon juice is not connected with the potash. So also, if my analyses are right for all samples, the opinion that the phosphoric acid is of consequence must be given up, as it is in such very small amount. Witt found the phosphoric anhydride rather more, as ·015 to ·038 per cent.

chant Shipping Act (1867) the same rule is ordered, except when the ship is in harbour, and fresh vegetables can be procured. It is mixed with sugar.

If dried vegetable can be procured, half the amount of juice will perhaps do.

In campaigns, when vegetables are deficient, the same rules should be enforced. On many foreign stations, where dysentery takes a scorbutic type (as formerly in Jamaica, and even of late years in China), lemon juice should be regularly issued.

Substitutes for Lemon Juice.

Citric acid is the best, or citrate of potash; then perhaps vinegar, though this is inferior, and lowest of all is nitrate of potash.* The tartrates, lactates, and acetates of the alkalies may all be used, but I am not aware of any good experiments on their relative anti-scorbutic powers. If milk is procurable, it may be allowed to become acid, and the acid then neutralised with an alkali. The fresh juices of many plants, especially species of Cacti, can be used, the plant being crushed and steeped in water; and in case neither vegetables, lemon juice, nor any of its substitutes can be procured, we ought not to omit the trial of such plants of this kind as may be obtainable.

* On this point see Bryson's paper in the "Medical Times and Gazette," 1850. I may also refer to a review on scurvy, which I contributed to the "British and Foreign Medical Chirurgical Review," in October 1848, for evidence on this point.

CHAPTER VIII.

SOILS.

TOPOGRAPHICAL REPORTS AND CHOICE OF SITES.

The term soil is used here in a large sense, to express all the portion of the crust of the earth, which by any property or condition can affect health. The subdivision into surface soil and subsoil is often very useful; and these terms need no definition.

SECTION I.

CONDITIONS OF SOIL AFFECTING HEALTH.

Soil may affect health :—

1. By its conformation and elevation.
2. By the vegetation covering it.
3. By its mechanical structure, which influences absorption and radiation of heat; reflection of light; absorption and retention of water; movement of water over and through the soil; passage of air through soil; formation of dust.
4. By its chemical structure, which acts especially by altering the composition of the air over the soil, or the water running through it.

In addition, the aspect of a place, and the amount of sunshine and light it receives, are very important.

All these points should receive attention in reports on sites; and it will be found convenient to make the report in the above order.

Sub-Section I.—Conformation and Elevation.

The relative amounts of hill and plain; the elevation of the hills; their direction; the angle of slope; the kind, size, and depth of valleys; the chief water-sheds, and the direction and discharge of the water-courses; the amount of fall of plains, are the chief points to be considered.

Among hills, the unhealthy spots are enclosed valleys, punch-bowls, any spot where the air must stagnate; ravines, or places at the head or entrance of ravines.

In the tropics, especially, ravines and nullahs are to be avoided, as they are often filled with decaying vegetation, and currents of air frequently traverse them. During the heat of the day the current of air is up the ravine; at night down it. As the hills cool more rapidly than the surrounding plains, the latter current is especially dangerous, as the air is at once impure and cold. The worst ravine is a long narrow valley, contracted at its outlet, so as to dam up the water behind it. A saddleback is usually healthy, if not

too much exposed; so are positions near the top of a slope. One of the most difficult points to determine in hilly regions is the probable direction of winds; they are often deflected from their course, or the rapid cooling of the hills at night produces alteration.

On plains, the most dangerous points are generally at the foot of hills, especially in the tropics, where the water, stored up in the hills, and flowing to the plain, causes an exuberant vegetation at the border of the hills.

A plain at the foot of hills may be healthy, if a deep ravine cuts off completely the drainage of the hill behind it.

The next most dangerous spots are depressions below the level of the plain, and into which therefore there is drainage. Even gravelly soils may be damp from this cause, the water rising rapidly through the loose soil from the pressure of higher levels.

Elevation acts chiefly by its effect in lessening the pressure of the air, and in increasing the rapidity of evaporation (see CLIMATE.) It has a powerful effect on marshes; high elevations lessening the amount of malaria, partly from the rapid evaporation, partly from the greater production of cold at night. Yet, malarious marshes may occur at great elevations, even 6000 feet (Erzeroum and Mexico).

SUB-SECTION II.—VEGETATION.

The effect of vegetation on ground is very important. In cold climates the sun's rays are obstructed, and evaporation from the ground is slow; the ground is therefore cold and moist, and the removal of wood renders the climate milder and dryer. The extent to which trees impede the passage of water through the soil is considerable.

In hot countries vegetation shades the ground, and makes it cooler. The evaporation from the surface is lessened; but the evaporation from the vegetation is so great as to produce a perceptible lowering effect on the temperature of a place.

The hottest and driest places in the tropics are those divested of trees.

Vegetation produces also a great effect on the movement of air. Its velocity is checked; and sometimes in thick clusters of trees or underwood the air is almost stagnant. If moist and decaying vegetation be a coincident condition of such stagnation, the most fatal forms of malarious disease are produced.

Vegetation may thus do harm by obstructing the movement of air; on the other hand, it may guard from currents of impure air. The protective influence of a belt of trees against malaria is most striking.

In a hygienic point of view, vegetation must be divided into herbage, brushwood, and trees; and these should be severally commented on in reports.

Herbage is always healthy. In the tropics it cools the ground, both by obstructing the sun's rays and by aiding evaporation; and nothing is more desirable than to cover, if it be possible, the hot sandy plains of the tropics with close-cut grass.

Brushwood is almost always bad, and should be removed. It must be remembered, however, that its removal will sometimes, on account of the disturbance of the ground, increase malarious disease for the time; and therefore, in the case of a temporary camp in a hot malarious country, it is often desirable to avoid disturbing it. When removed, the work should be carried on in the heat of the day, *i.e.*, not in the early morning, or in the evening.

Trees should be removed with judgment. In cold countries they shelter

from cold winds; in hot, they cool the ground; in both, they may protect from malarious currents. A decided and pernicious interference with the movement of air should be almost the only reason for removing them. In some of the hottest countries of the world, as in Southern Burmah, the inhabitants place their houses under trees with the best effects; and it was a rule with the Romans to encamp their men under trees in all hot countries.

The kind of vegetation, except as being indicative of a damp or dry soil, does not appear to be of importance.

Sub-Section III.—Mechanical Structure.

(*a.*) *As influencing Heat.*—The heat of the sun is absorbed in different amounts by different soils equally shielded or unshielded by vegetation. The colour of the soil and its aggregation seem chiefly to determine it. The dark, loose, incoherent sands are the hottest; even in temperate climates Arago found the temperature of sand on the surface to be 122° Fahr., and at the Cape of Good Hope, Herschel observed it to be no less than 159°.* The heating power of the sun's rays is indeed excessive. In India, the thermometer placed on the ground and exposed to the sun will mark 160° (Buist), while two feet from the ground it will only mark 120°. Buist thinks that if protected from currents of air it would mark 212° when placed on the ground. The absorbing and radiating powers of soils are not necessarily equal, though they may be so. Generally the radiating power is more rapid than the absorbing; soils cool more rapidly than they heat. Some of the marshes in Mexico cool so rapidly at night that the evolution of malaria is stopped, and the marsh is not dangerous during the night. A thermometer marked 32° Fahr. on the ground, while 16 feet above the ground it marked 50° Fahr. (Jourdanet).

With regard to absorbing power, the following table by Schübler contains the only good experiments at present known:—

Power of retaining heat; 100 *being assumed as the standard.*

Sand with some lime, .	100	Clayey earth, . . .	68·4
Pure sand, . . .	95·6	Pure clay, . . .	66·7
Light clay, . . .	76·9	Fine chalk, . . .	61·8
Gypsum, . . .	73·2	Humus, ...	49
Heavy clay, . . .	71·11		

The great absorbing power of the sands is thus evident, and the comparative coldness of the clays and humus. Herbage lessens greatly the absorbing power of the soil, and radiation is more rapid. On the Orinoco a naked granite rock has been known to have a temperature of 118° Fahr., while an adjacent rock, covered with grass, had a temperature 32° lower.

In cold countries, therefore, the clayey soils are cold, and as they are also damp, they favour the production of rheumatism and catarrhs; the sands are, therefore, the healthiest soils in this respect. In hot countries the sands are objectionable from their heat, unless they can be covered with grass. They sometimes radiate heat slowly, and therefore the air is hot over them day and night.

The sun's rays cause two currents of heat in soil: one wave diurnal, the heat passing down in temperate climates to about four feet in depth during the day, and receding during the night—the depth, however, varying with the nature of the soil, and with the season; the other wave is annual, and

* Meteorology, p. 4

in temperate climates the wave of summer heat reaches from 50 to 100 feet. The line of uniform yearly temperature is from 57 to 99 feet below the surface (Forbes).

Not only does the amount of radiation differ in different soils, but a change is produced in the heat by the kind of soil. The remarkable researches of Tyndall have shown,* that the heat radiated from granite passes through aqueous vapour much more readily than the heat radiated by water (though the passage is much more obstructed than in dry air). In other words, the luminous heat rays of the sun pass freely through aqueous vapours, and fall on water and granite; but the absorption produces a change in the heat, so that it issues again from water and granite changed in quality; it will be most important for physicians if other soils are found to produce analogous changes.

With regard to the effect of temperature of the soil on disease, it can hardly be doubted that it powerfully influences malaria, and probably also aids the progress of cholera.

(*b.*) *Reflection of Light.*—This is a matter of colour; the white glaring soils reflect light, and such soils are generally also hot, as the rays of heat are also reflected. The effect of glare on the eyes is obvious, and in the tropics this becomes a very important point. If a spot bare of vegetation, and with a white surface, must be used for habitations, some good result might be obtained by colouring the houses pale blue or green.

(*c.*) *Absorption and Retention of Water.*—Some soils absorb and retain water more than others; and some experiments have been made by Schübler on this point. Sand absorbs very little;† clays about ten to twenty times more; and humus or common surface soil more than forty or fifty times as much as sand. Some soils retain water with great tenacity. After several months of long-continued drought, Mr Church found a light calcareous clay-loam subsoil, resting on the Forest marble, contain from 19 to 28 per cent. of water.

Loose sand will sometimes hold 2 gallons of water in a cubic foot (Anster). Ordinary sandstone will hold one gallon.

Clays often contain as much as 10 per cent. of water by weight; the driest granites and marbles from ·4 to 4 per cent. by weight, or about a pint in each cubic yard. It is said that the soil from disintegrated granite or trap rock is very absorbent of water, as in the case of the black or so-called cotton soil of India, which is derived from trap.

The absorption of water seems important in two ways: 1*st*, Such soils are moist; 2*d*, If they contain organic matter the moisture aids in its decomposition, and such soils, though not rich in organic matter, may be malarious.

(*d.*) *Movement of Water over and through Soils.*—No soils are absolutely impermeable to water, but practically a division can be made into the impermeable and the permeable soils. The impermeable soils, into which, perhaps, not more than 5 to 10 per cent. of the rain penetrates, are the granitic and trap rocks; the clay slates; the hard sandstones, such as the millstone grit; the hard limestones and magnesian limestones, such as the mountain limestone, and dolomites, and the clays. Some kinds of clay are as impermeable to water as the hardest rocks, and the addition of even $\frac{1}{12}$th part of clay to sand checks in an extraordinary degree the transit of water.

Of the above soils, on some the water runs off, as in the granite, clay-slates, &c.; in others, it lodges, as in the clays. This is a sequence merely

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* Chemical News, March 5, 1864, p. 114.

† Pfaff (Zeitsch. für Biol., band iv. p. 255) found quartz sand absorb more than Schübler states; in a filter he found the sand took up 20 per cent. of its weight, but less when in its natural position.

of conformation; the hard rocks having for the most part a great slope, the clays being flat.

The permeable soils are the sandstones (except when traversed by veins of clay), the loose sands and the chalk, except where marly. Of the water falling on these soils, 25 per cent. penetrates into the sandrocks, about 42 per cent. penetrates into the chalk, and from 60 to 96 per cent. into the loose sands. The water passes rapidly through the soil. These very permeable soils are healthy, unless either a clay stratum or a hard rock a few feet below the surface holds up the water, and makes the sand moist by evaporation, which can be always detected by boring holes; or unless the soil also contains a large quantity of organic matter, of which an example is given farther on.

The amount and the variation in the level of the water in the soil are points which have now acquired increased interest from the following investigations:—

(*a.*) The observations of Buchanan* that the death-rate from phthisis in various towns in England has greatly fallen in consequence of efficient land drainage and consequent removal of the subsoil water, is of singular interest. The facts are numerous, and unless we are to disbelieve altogether in the correctness of the Registration returns, we must, I think, admit that, as Mr Simon expresses it, "dampness of soil is an important cause of phthisis to the population living on the soil."

(*b.*) The statement of Pettenkofer that a varying level of the subsoil or ground water is one of the necessary elements in the production of an outbreak of cholera and typhoid fever.† Whatever may be the ultimate fate of this hypothesis, it is impossible to deny that the evidence points to some influence exerted over the spread of cholera and typhoid in certain cases, though whether, as Pettenkofer believes, it is one of the principal factors, is uncertain.

As a rule, then, the dry soils, whether impermeable or permeable, are healthy; not only is there less disease (catarrhs, rheumatism), but persons feel better, and nutrition seems better performed.

(*e.*) *Passage of Air through Soils.*—Some of Pettenkofer's observations show that a very large amount of air is contained even in firm soils, and effluvia from decomposing substances may pass for a long distance through very loose soils. It is a practical point of importance, especially on the sandy plains of India, to see that there is no chance of transmission of disease in this way.

(*f.*) The amount of dust given off from soils is not a matter of slight moment. Apart from its inconvenience, the irritation has a decided effect on the eyes, and possibly even on the lungs and stomach, though on this point the evidence is not satisfactory.

Sub-Section IV.—Chemical Composition.

The chemical composition of the soil is important as affecting drinking water and air. The first point has been fully considered in the chapter on Water.

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* Report of the Medical Officer of Health to the Privy Council, ninth and tenth Reports. Dr Bowditch of Boston drew attention, in 1862, to the connection between phthisis and soil-moisture, but his observations escaped notice in this country until Dr Buchanan's independent discovery led to a fuller discussion of the subject.

† Several very striking papers by Pettenkofer, Buhl, Griessenkerl, Seidel, Cordes, Delrüch, Zeroni, and others, are contained in the Zeitsch. für Biologie on Cholera and Typhoid. The evidence is strong, as in the case of Lyons, lately debated so carefully by Pettenkofer, but there are several instances of outbreaks of cholera not easily reconcilable with this view.

As regards air, some gases, such as carburetted hydrogen, ammonia, sulphuretted hydrogen, are given off by certain soils. Diffusion and the wind, for the most part, so rapidly dissipate these gases that they produce no bad effects. Organic matters are also given off, the nature of which is not yet known (see Air over Marshes, p. 94).

It can hardly be doubted that it is some of these organic matters which produce the remarkable fevers with periodical returns, for I presume it may now be assumed that such fevers are not produced by heat or electricity, or great exercise in the sun, or any other alleged cause of the kind, but must own a special and constant agent which can hardly be a gas. It is apparently some kind of decomposition or fermentation going on in the soil, especially when the conditions come together of organic matter in the soil, of moisture, heat, and limited access of air.

If it be asked, What exact chemical conditions of soil produce the malaria which causes periodical fevers? the answer cannot be given, because no great chemist has ever systematically prosecuted this inquiry, and, in fact, it may be said that, singularly enough, there are few good analyses of malarious soil, although no problem is perhaps more important to the human race. It seems pretty clear that the mineral constituents of the soil are of little or no consequence. Malaria will prevail on chalk, limestone, sand, and even, under special conditions, on granite soils.

The following soils have been known to cause the evolution of the agent causing periodical fevers in the malarious zone.

1. *Marshes.*—Except those with peaty soils, those which are regularly overflowed by the sea (and not occasionally inundated),* and the marshes in the southern hemisphere (Australia, New Zealand, New Caledonia), and some American marshes, which, from some as yet unknown condition, do not produce malaria.

The chemical characters of well-marked marshes are a large percentage of water, but no flooding; a large amount of organic matter (10 to 45 per cent.) with variable mineral constituents; silicates of alumina; sulphates of lime, magnesia and alkalies; carbonate of lime, &c. The surface is flat, with a slight drainage; vegetation is generally abundant.

The analyses of the worst malarious marshes show a large amount of vegetable organic matter. A marsh in Trinidad gave 35 per cent.; the middle layer in the Tuscan Maremma 30 per cent. The organic matter is made up of humic, ulmic, crenic, and apocrenic acids—all substances which require renewed investigation at the hands of chemists. Vegetable matter embedded in the soil decomposes very slowly; in the Tuscan Maremma, which must have existed many centuries, if not thousands of years, many of the plants are still undestroyed. The slow decomposition is much aided by heat, which makes the soil alkaline from ammonia (Angus Smith), and retarded by cold, which makes the ground acid, especially in the case of peaty soils.

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* The effect of salt water on marshes is a problem which has been much debated, and I believe the statement in the text reconciles most opinions. It was the older writers (Sylvius, Lancisi, and Pringle) who insisted on the noxious qualities of exhalations from marshes with water containing salt, and there is certain evidence that the occasional overflowing of the sea in some of the Italian marshes, for example, has been followed by a great development of paroxysmal fevers. But there is much evidence similar to that given by Robert Jackson, who says ("Fevers in Jamaica," 1791, p. 4):—"I have never found the neighbourhood of salt marshes, in the different parts of America that I have had an opportunity of visiting, less healthful than the rest of the country; on the contrary, they were frequently more so." And the case of Singapore, which has created such surprise, and is cited even by Hirsch as an exceptional case, is of this kind; the regular tidal overflow, though it causes the development of much sulphuretted hydrogen, prevents the formation of malaria.

It would now seem tolerably certain that the growing vegetation covering marshes has nothing to do with the development of malaria.

2. *Large collection of Vegetable Matter in the soils of Valleys, Ravines, &c.*

3. *Sandy Plains.*—The analysis of such sand has not been yet properly made, but two conditions seem of importance. Some sands, which to the eye appear quite free from organic admixture, contain much organic matter. Fauré has pointed out that the sandy soil of the Landes in south-west France contains a large amount of organic matter, which is slowly decomposing, and passes into both air and water, causing periodical fevers. This may reasonably be conjectured to be the case with other malarious sands. Then, under some sands, a few feet from the surface, there is clay, and the sand is moist from evaporation. Under a great heat a small quantity of organic matter may thus be kept in a state of change. This is especially the case along the dried beds of water-courses and torrents; there is always a subterranean stream, and the soil is impregnated with vegetable matter. In other cases the sands may be only malarious during rains when the upper stratum is moist.

4. *Certain Hard Rocks and Disintegrated Rocks are said to be Malarious.*—In Brazil ("M'William on Yellow Fever in Brazil," p. 7), and in the Mysore country of India, certain dark granitoid or metamorphic trap or hornblendic rocks are said to give rise to fever,* and the same statement has been made in respect of the weathered and disintegrated granite of Hong-Kong. In fact, many Indian surgeons entertain a strong opinion of the unhealthiness of disintegrated granite. The statement (Heyne of Madras) that iron hornblende is concerned in the production of periodical fevers is now known to be incorrect, as several healthy stations in India (Himalaya stations) are situated on such rocks. Richter also states† that observations on the Saxon hills entirely contradict Heyne's statements.

The disintegrated granite of Hong-Kong contains a small proportion of organic matter,‡ which could hardly produce malaria. Friedel,§ however, has stated that the disintegrated granite, which is highly absorbent of water, becomes often permeated by a fungus, and it would be interesting to see if there is any relation between the development of this fungus and the production of malaria.

The magnesian limestone rocks which have been subjected to volcanic action have also been supposed to be especially malarious (Kirk, who instances the rocks at Sukkar), but the evidence has not been yet corroborated.

5. *Iron Salts.*—Sir Ranald Martin has directed attention to the fact that many reputed malarious soils contain a large proportion of iron. No good evidence has been adduced that this is connected with malaria, but the point is well worthy of investigation. Boussingault has pointed out that the oxides of iron in clays aid in the absorption of oxygen; the peroxide of iron is an oxidising agent, giving off an atom of oxygen to an oxidisable substance, and again taking an atom of oxygen from the air. It is therefore possible that it may aid in a partial oxidation of vegetable matter. But certainly many most healthy soils contain a large amount of iron.

A medical officer is often placed in a very difficult position when he has to give an opinion on the probability of a soil (not evidently marshy) being free from malaria or not. Two points must be considered :—

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* The syenite of Brazil becomes coated by a dark substance, and looks like plumbago, and the Indians believe that rocks thus blackened cause "calentura," or fevers.

† Schmidt's Jahrb. 1864, No. 5, p. 240.

‡ An analysis made in the Army Medical School Laboratory shows less than 2 per cent. of organic matter in a sample of disintegrated granite from Hong-Kong.

§ Ost Asiens, von C. Friedel, 1863.

1. Can malaria be drifted to the place in any way; how far off are decided marshes; do winds blow over such marshes; are there any protective eminences or belts of trees? It must be remembered that in the tropics currents of air will pass for some distance from the banks of rivers, or from ground covered with vegetation, over hot plains, from which heated air ascends by night as well as by day, so that a place in this way may become malarious.

2. Can malaria be generated on the spot itself? Of course the character of a marsh cannot be mistaken, but there may be no marsh; then the soil and subsoil should be thoroughly examined; deep holes dug to find the depth of water, and this should be done in the wet season, if possible, and the amount of organic matter in the soil should be determined. In this way a conclusion can generally be come to; but in all cases, if possible, let an actual trial be made of the place, supposing it be intended for a permanent cantonment.

The following table condenses some of these points :—

Soils with the largest Organic Emanations.

1. Alluvial soils, old estuaries, deltas, &c. Peaty soils are much less malarious. Marshes overflowed regularly by the sea are often healthy. The occasional admixture of salt water increases the emanations.
2. Sands, if there is an impermeable clay or marly subsoil. Old water-courses.
3. The lower parts of the chalk, when there is a subsoil of gault or clay.
4. Weathered granitic and trap rocks, if vegetable matter has become intermixed. Such soils absorb both heat and water.
5. Rich vegetable soils at the foot of hills.

SECTION II.

GENERAL OBSERVATIONS ON THE HEALTHINESS OF SOILS.

It is of course always useful to know the geological formation of a place, but the value of this knowledge must not be overrated. A geological formation may include rocks of very various mechanical and chemical composition. In many cases we want to know the condition as to permeability, organic substance, or moisture of a very limited area; so to speak, it is the house, and not the regional, geology which is of use to us. Still, geological terms have their value for our purpose, as expressing, in some cases, the usual conditions of conformation, and mechanical and chemical properties.

1. *The Granitic, Metamorphic, and Trap Rocks.*—Sites on these formations are usually healthy; the slope is great, water runs off readily; the air is comparatively dry; vegetation is not excessive; marshes and malaria are comparatively infrequent, and few impurities pass into the drinking water. It has been noticed that Asiatic cholera is infrequent in houses seated on such rocks, as well as on hard volcanic rocks, and this has been attributed to unknown influences excited by such formations on the air; the cause is, most probably, as Pettenkofer has pointed out, merely that the cholera stools do not penetrate into the soil, but are carried off by the steep slope and rapid falls of rain. As such regions are also often elevated, strong currents of air are more frequent, and the particles derived from the dried stools are carried away.

When these rocks have been weathered and disintegrated, they are supposed to be unhealthy. Such soil is absorbent of water; and the disintegrated granite of Hong-Kong is said to be rapidly permeated by a fungus; but evidence as to the effect of disintegrated granite or trap is really wanting.

2. *The Clay Slate.*—These rocks precisely resemble the granite and granitoid formations in their effect on health. They have usually much slope; are very impermeable; vegetation is scanty; and nothing is added to air or to drinking water.

They are consequently healthy. Water, however, is often scarce; and, as in the granite districts, there are swollen brooks during rain, and dry watercourses at other times swelling rapidly after rains.

3. *The Limestone and Magnesian Limestone Rocks.*—These so far resemble the former, that there is a good deal of slope, and rapid passing off of water. Marshes, however, are more common, and may exist at great heights. In that case the marsh is probably fed with water from some of the large cavities, which, in the course of ages, become hollowed out in the limestone rocks by the carbonic acid of the rain, and form reservoirs of water.

The drinking water is hard, sparkling, and clear. Of the various kinds of limestone, the hard oolite is the best, and magnesian is the worst; and it is desirable not to put stations on magnesian limestone if it can be avoided.

4. *The Chalk.*—The chalk, when unmixed with clay and permeable, forms a very healthy soil. The air is pure, and the water though charged with carbonate of lime, is clear, sparkling, and pleasant. Goitre is not nearly so common, nor apparently calculus, as in the limestone districts.

If the chalk be marly, it becomes impermeable, and is then often damp and cold. The lower parts of the chalk, which are underlaid by gault clay, and which also receive the drainage of the parts above, are often very malarious; and in America, some of the most marshy districts are on the chalk.

5. *The Sandstones.*—The permeable sandstones are very healthy; both soil and air are dry; the drinking water is, however, sometimes impure. If the sand be mixed with much clay, or if clay underlies a shallow sand-rock, the site is sometimes damp. In choosing such a site, the water should be always carefully examined.

The hard millstone grit formations are very healthy, and their conditions resemble those of granite.

6. *Gravels* of any depth are always healthy, except when they are much below the general surface, and water rises through them. Gravel hillocks are the healthiest of all sites, and the water, which often flows out in springs near the base, being held up by underlying clay, is very pure.

7. *Sands.*—There are both healthy and unhealthy sands. The healthy are the pure sands, which contain no organic matter, and are of considerable depth. The air is pure, and so is often the drinking water. Sometimes the drinking water contains enough iron to become hard, and even chalybeate. The unhealthy sands are those which, like the subsoil of the Landes, in south-west France, are composed of siliceous particles (and some iron), held together by a vegetable sediment. It is nearly impermeable to water, but water dissolves gradually the vegetable matter, and acquires a brownish-yellow colour, and, if it comes from about 6 feet in depth, has a marshy odour. It is most unwholesome, and causes intermittents and visceral engorgements.* Chemical and microscopic analysis will detect this condition.

In other cases sand is unhealthy, from underlying clay or laterite near the surface, or from being so placed that water rises through its permeable soil from higher levels. Water may then be found within 3 or 4 feet of the surface; and in this case the sand is unhealthy, and often malarious. Impurities are retained in it, and effluvia traverse it. Merely digging for water in the wet season will cause the discovery of these conditions.

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* Eaux Publiques, par De Caux, p. 155.

In a third class of cases, the sands are unhealthy because they contain soluble mineral matter. Many sands (as, for example, in the Punjab) contain much carbonate of magnesia and lime salts, as well as salts of the alkalies. The drinking water may thus contain large quantities of sodium chloride, sodium carbonate, and even lime and magnesian salts and iron. Without examination of the water, it is impossible to detect these points.

8. *Clay, Dense Marls, and Alluvial Soils generally.*—These are always to be regarded with suspicion. Water neither runs off nor runs through; the air is moist; marshes are common; the composition of the water varies, but it is often impure with lime and soda salts. In alluvial soils there are often alternations of thin strata of sand, and sandy impermeable clay; much vegetable matter is often mixed with this, and air and water are both impure. Vast tracts of ground in Bengal and in the other parts of India, along the course of the great rivers (the Ganges, Brahmapootra, Indus, Nerbudda, Krishna, &c.), are made up of soils of this description, and some of the most important stations even up country, such as Cawnpore, are placed on such sites. If such spots must be chosen, thorough subsoil draining, careful purification of water, and elevation of the houses far above the soil, are the measures which must be adopted. It has been considered (Forbes Watson) that nearly one-third of the whole surface of India is covered by alluvial soil.

The Deltas of great rivers present these alluvial characters in the highest degree, and should not be chosen for sites. If they must be taken, only the most thorough drainage can make them healthy. It is astonishing, however, what good can be effected by the drainage of even a small area, quite insufficient to affect the general atmosphere of the place; this shows that it is the local dampness and the effluvia which are the most hurtful.

9. *Cultivated Soils.*—Well-cultivated soils are often healthy, nor at present has it been proved that the use of manure is hurtful. Irrigated lands, and especially rice fields, which not only give a great surface for evaporation, but also send up organic matter into the air, are hurtful. In Northern Italy, where there is a very perfect system of irrigation, the rice grounds are ordered to be kept 14 kilometres (= 8·7 miles) from the chief cities; 9 kilometres (= 5·6 miles) from the lesser cities and the forts; and 1 kilometre (= 1094 yards) from the small towns. In the rice countries of India this point should not be overlooked.

SECTION III.

EXAMINATION OF SOIL.

Mechanical Condition of Soil.—The degree of density, friability, and penetration by water, should be determined both in the surface and subsoil. Deep holes, 6 to 12 feet, should be dug, and water poured on portions of the soil. Holes should be dug after rain, and the depth to which the rain has penetrated observed. In this way the amount of dryness, the water-level, and the permeability, can be easily ascertained.

The surface or subsoil can also be mechanically analysed by taking a weighed quantity (1000 grains), drying it, and then picking out all the large stones and weighing them, passing through a sieve the fine particles, and finally separating the finest particles from the coarser by mixing with water, allowing the denser particles to subside, and pouring off the finer suspended particles. The weight of the large stones, plus the weight of the stones in the sieve and of the dried coarser particles, deducted from the total weight,

gives the amount of the finely divided substance, which is probably silicate of alumina.

Temperature.—The temperature at a depth of 2 or 3 feet, at 2 to 4 o'clock in the afternoon, would be an important point to determine in the tropics, and also the temperature in early morning. At present such observations, though very easily taken, and obviously very instructive, are seldom, if ever, made. It might be also useful to take a certain depth of soil, say 6 inches, and placing a thermometer in it, determine the height of the thermometer on exposure to the sun's rays for a given time at a certain hour.

Chemical Examination.—The chemical constituents of soil are, of course, as numerous as the elements; more than 500 minerals have been actually named. But certain substances are very rare, and, for the physician, the chief constituents of soils are the following substances or combinations. Silica, alumina, lime, iron, magnesia, chlorine, carbonic acid, phosphoric acid, nitric acid. A few simple tests are often very useful, if we are uncertain what kind of rock we have to deal with. Few persons could mistake granite, trap, gneiss, or rocks of that class; or clay-slate or crystalline limestone. But fine white sandstones, or freestone, or even fine millstone grit, might be confounded with lime rocks, or magnesian limestone. A few drops of hydrochloric acid will often settle the question, as it causes effervescence in the carbonates of lime and magnesian rocks.*

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* It may be useful to give (from Page's "Handbook of Geological terms") a few compositions, and to define a few of the common mineralogical words used in geology.

Quartz.—Crystallised silica.

Felspar.—Silica, alumina (trisilicate of alumina), potash or soda, and a little lime, magnesia, and ferric oxide, crystallised or amorphous.

Mica.—Silica, alumina, ferric oxide and potash, or magnesia, or lime, or lithia.

Chlorite.—Mica, but with less silica and more magnesia and iron.

Granite.—Composed of quartz, felspar, and mica.

Syenite.—Hornblende instead of mica.

Syenitic granite.—Quartz, felspar, mica, and hornblende.

Gneiss.—Same elements as granite, but the crystals of quartz and felspar are broken and indistinct.

Hornblende.—A mineral entering largely into granitic and trappean rocks, composed of silica (46 to 60), magnesia (14 to 28), lime (7 to 14), with a little alumina, fluorine, and ferrous oxide.

Augite.—Like hornblende, only less silica (does not resist acids).

Hypersthene.—Like augite, only with very little lime; it contains silica, magnesia, and iron; resists acids.

Greenstone.—Hard granular crystalline varieties of trap, felspar, and hornblende, or felspar and augite.

Basalt.—Augite and felspar, olivine, iron, pyrites, &c.

Trap.—Tabular greenstone and basalt.

Schist.—A term applied to the rocks mentioned above, when they are foliated or split up into irregular plates.

Clay-Slate.—Argillaceous arenaceous rocks, with more or less marked cleavage.

Limestone.—All varieties of hard rocks, consisting chiefly of carbonate of lime.

Oolite.—Limestone made up of small rounded grains, compact or crystalline, like the roe of a fish.

Chalk.—Soft calcium carbonate.

Magnesian limestone.—Any limestone containing 20 per cent. of a salt of magnesia, frequently not crystallised.

Dolomite.—Crystallised magnesian limestone.

Kunkur.—A term used in India to denote nodular masses of impure calcium carbonate.

Gypsum—Selenite.—Sulphate of lime.

Gravel.—Water-worn and rounded fragments of any rock, chiefly quartz; size, from a pea to a hen's egg.

Sand.—Same, only particles less than a pea.

Sandstone.—Consolidated sand; the particles held together often by lime, clay, and ferric oxide.

Freestone.—Any rock which can be cut readily by the builder; usually applied to sandstone.

Millstone grit.—Hard gritty sandstone of the carboniferous series, used for millstones. Grit is the term generally used when the particles are larger and sharper than in ordinary sandstone.

A more complete examination should include the following points :—

1. *Percentage of Water.*—Take 100 grains of a fair sample of soil, and dry at a heat of 220°; weigh again; the difference is water or volatile substance. Percentage of volatile matters (including water), destroyed by incineration. Take another weighed portion of soil and incinerate at a full red heat; re-carbonate with carbonic acid solution, or with ammonium carbonate; heat to expel excess of ammonia; dry and weigh.

2. *Absorption of Water.*—Place the dried soil in a still atmosphere, on a plate in a thin layer, and reweigh in 24 hours; the increase is the absorbed water. An equal portion of pure sand should be treated in the same way as a standard. It would be well to note the humidity of the air at the time.

3. *Power of holding Water.*—Thoroughly wet 1000 grains, drain off water as far as possible, and weigh; the experiment is, however, not precise.

4. *Substances taken up by Water.*—This is important, as indicating whether drinking water is likely to become contaminated. Rub thoroughly 100 grains in pure cold water, filter and test for organic matter by chloride if good, or by evaporation and careful incineration; test also for chlorine, sulphuric acid, lime, alumina, iron, nitric acid (see WATER, page 32, for the several tests).

5. *Substances taken up by Hydrochloric Acid.*—While water takes up the chlorides and the sulphates of the alkalies, nitrates, &c., the greater part of the lime, magnesia, and alumina, are left undissolved. This quantity can be best determined by solution in pure hydrochloric acid.

(*a.*) To 400 grains of the soil add 1 ounce of pure hydrochloric acid, and heat; note effervescence. Add about 3 ounces of water. Digest for 12 hours. Dry and weigh the undissolved portion.

(*b.*) To the acid solution add ammonia. Alumina and oxide of iron are thrown down. Dry and weigh precipitate.

(*c.*) To the filtered solution add ammonium oxalate. Dry; wash and burn the calcium oxalate. Weigh as carbonate (see page 50).

(*d.*) To the solution filtered from (*c*) add sodium phosphate. Collect; dry and weigh (100 grains of the precipitate = 79 grains of magnesium carbonate); or determine as pyrophosphate. (See WATER.)

The portion insoluble in hydrochloric acid consists of quartz, clay, silicates of alumina, iron, lime, and magnesia. If it is wished to examine it further, it should be fused with three times its weight of carbonate of soda, then heated with dilute hydrochloric acid. The residue is silica. The solution may contain iron, lime, magnesia, and alumina. Test as above.

6. *Iron.*—Iron can be determined by the bichromate of potash, or by the permanganate. As the latter solution is used for other purposes, it is convenient to employ it in this case.

Dissolve in 100 grains of the soil in pure hydrochloric acid, free from iron, by heat.

Add a little pure zinc and heat to convert peroxide into protoxide. Determine iron by potassium permanganate; *i.e.*, heat to 140°, and then drop in the

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Greensand.—Lower portion of the chalk system in England; sand coloured by chloritous silicate of iron.

Clay.—Silicate of alumina.

Marl.—Lime and clay.

Laterite.—A term much used in India to denote a more or less clayey stratum which underlies much of the sand in Bengal, some parts of Burmah, Bombay presidency, &c.

Conglomerate.—Rocks composed of consolidated gravels (*i.e.*, the fragments water-worn and rounded).

Breccia.—Rocks composed of *angular* (not water-worn) fragments (volcanic breccia, osseous breccia, calcareous breccia).

Shale.—A term applied to all clayey or sandy formations with lamination; it is often consolidated and hardened mud.

solution of permanganate till a permanent but very slight red colour is given.

Preparation of Potassium Permanganate Solution.

The solution made for the determination of organic matter in water may be used, or the following may be substituted.

Take 10 C.C. of standard solution of oxalic acid (63 grammes to 1 litre) and add 90 C.C. of water (= 100 C.C. of decinormal acid). Add 2 C.C. of strong sulphuric acid, and heat to 140° Fahr.

Drop into it solution of permanganate of potash.

The number of C.C. of the permanganate used = 0·56 grammes of pure iron. Multiply by 15·43 to bring into grains. A simple calculation will then show to how many grains of iron 1 C.C. of the permanganate solution corresponds.

SECTION IV.

GENERAL RULES FOR CHOICE OF SITE.

If a site is to be chosen for a permanent station, see it at all times of the year and of the day; in the wet as well as in dry season, and at night as well as by day.

Height of Hills.—Get the exact height of the hills from an engineer; or failing this, determine it by the barometer. (See METEOROLOGY.)

Geological Order, Direction, and Dip of Strata.—Learn the position in the geological series, if possible, the direction of the dip of the strata, and the course of the fall of water.

Mechanical and Chemical Composition.—Get as much information as possible in the way already pointed out; even a superficial examination is much better than nothing.

Analysis of Water.—Analyse the water, and determine its quantity.

Subterranean course of Water.—Always choose a spot from which there is drainage, and into which there is no drainage.

Temperature, Dew-point, and Winds.—Take as many temperature observations as possible, and dew-point determinations, and learn the direction of the winds, and, if possible, their force and temperature. Attend to all the rules already given on confirmation, vegetation, and composition of soil, and dig holes of 10 to 16 feet in depth at various points. If possible, never take ground which has been much disturbed, and always avoid sites of old dwellings.

Such a complete examination demands time and apparatus, but it is quite necessary.

A fair opinion can then be formed; but if a large permanent station is to be erected, it is always desirable to recommend that a temporary station should be put up for a year, and an intelligent officer should be selected to observe the effect on health, to take meteorological observations, and to examine the water at different times of the year. Sometimes a spot more eligible than that originally chosen may be found within a short distance, and the officer should be instructed to keep this point in view.

The medical officer has nothing to do with military considerations or questions of supply, but if he is able to suggest anything for the information of the authorities, he should of course do so.

The opinion of Lind, whose large experience probably surpassed that of his contemporaries, and of our own time, should be remembered.*

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* "The most healthy countries in the world contain spots of ground where strangers are subject to sickness. There is hardly to be found any large extent of continent, or even any island,

In choosing a site for a temporary camp, so elaborate an examination is not possible. But as far as possible the same rules should be attended to. There is, however, one difference—in a permanent station water can be brought from some distance; in a temporary station the water supply must be near at hand, and something must be given up for this. The banks of rivers, if not marshy, may be chosen, care being taken to assign proper spots for watering, washing, &c., as laid down in the chapter on WATER. A river with marshy banks must never be chosen in any climate, except for the most imperative military reasons; it is better to have the extra labour of carrying water from a distance.

A site under trees is good in hot countries, but brushwood must be avoided.

SECTION V.

PREPARATION OF SITE.

In any locality intended to be permanently used, the ground should be drained with pipe drains. Even in the driest of the loose soils this is desirable, especially in hot climates, where the rain-fall is heavy. In impermeable rocky districts it is less necessary. The size, depth, and distance of the drains will be for the engineer to determine; but generally deep drains (4 to 8 feet in depth, and 12 to 18 feet apart) are the best. If there is no good fall, it has been proposed to drain into deep pits; but usually an engineer will get a fall without such an expedient. A good outfall, however, should be a point always looked to in choosing a station. These drains are intended to carry off subsoil water, and not surface water. This latter should be provided for by shallow drains along the natural outfalls and valleys. As far as drainage is concerned, we have then to provide for mere surface water, and for the water which passes below the surface into the soil and subsoil.

Brushwood should be cleared away, but trees left until time is given for consideration. In clearing away brushwood, the ground in the tropics should be disturbed as little as possible; and if it can be done, all cleared spots should be soon sown with grass.

In erecting the buildings, the ground should be excavated as little as possible; in the tropics, especially, hills should never be cut away. The surface should be levelled, holes filled in, and those portions of the surface on which rain can fall from buildings well paved, with good side gutters. This is especially necessary in the tropics, where it is of importance to prevent the ground under buildings from becoming damp; but the same principles apply everywhere.

In a temporary camp so much cannot be done; but even here it is desirable to trench and drain as much as possible. It not unfrequently happens in war that a camp intended to stand for two or three days is kept up for two or three weeks, or even months. As soon as it is clear that the occupation is to be at all prolonged, the same plans should be adopted as in permanent stations. The great point is to carry off water rapidly, and it is astonishing what a few well-planned surface drains will do.

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that does not contain some places where Europeans may enjoy an uninterrupted state of health during all seasons of the year."—Lind, *Diseases of Europeans in Hot Climates*, 4th edition, p. 200.

CHAPTER IX.

HABITATIONS.

WHOEVER considers carefully the record of the mediæval epidemics, and seeks to interpret them by our present knowledge of the causes of disease, will, I believe, become convinced that one great reason why those epidemics were so frequent and so fatal was the compression of the population in faulty habitations. Ill-contrived and closely packed houses, with narrow streets, often made winding for the purpose of defence; a very poor supply of water, and therefore a universal uncleanliness; a want of all appliances for the removal of excreta; a population of rude, careless, and gross habits, living often on innutritious food, and frequently exposed to famine from their imperfect system of tillage,—such were the conditions which almost throughout the whole of Europe enabled diseases to attain a range, and to display a virulence, of which we have now scarcely a conception. The more these matters are examined, the more, I believe, shall we be convinced that we must look, not to grand cosmical conditions; not to earthquakes, comets, or mysterious waves of an unseen and poisonous air; not to recondite epidemic constitutions, but to simple, familiar, and household conditions, to explain the spread and fatality of the mediæval plagues.

The diseases arising from faulty habitations are in great measure, perhaps entirely, the diseases of impure air. The site may be in fault; and from a moist and malarious soil excess of water and organic emanations may pass into the house. Or ventilation may be imperfect, and the exhalations of a crowded population may accumulate and putrefy; or the excretions may be allowed to remain in or near the house; or a general uncleanliness, from want of water, may cause a persistent contamination of the air. And, on the contrary, these five conditions insure healthy habitations:—

1. A site dry and not malarious, and an aspect which gives light and cheerfulness.
2. A ventilation which carries off all respiratory impurities.
3. A system of immediate and perfect sewage removal, which shall render it impossible that the air shall be contaminated from excreta.
4. A due supply and proper removal of water; by means of which perfect cleanliness of all parts of the house can be insured.
5. A construction of the house which shall insure perfect dryness of the foundation, walls, and roof.

In other words, perfect purity and cleanliness of the air are the objects to be attained. This is the fundamental and paramount condition of healthy habitations; and it must over-ride all other considerations. After it has been attained, the architect must engraft on it the other conditions of comfort, convenience, and beauty.

The military habitations which have to be considered are barracks and their adjuncts, and hospitals.

In the chapter on Field Service temporary war buildings will be considered.

SECTION I.

BARRACKS.

Barracks have been in our army, and in many armies of Europe still are, a fertile source of illness and loss of service. At all times the greatest care is necessary to counteract the injurious effects of compressing a number of persons into a restricted space. In the case of soldiers, the compression has been extreme; but the counteracting care has been wanting. It is not more than forty years since, in the West Indies, the men slept in hammocks touching each other, only twenty-three inches of lateral space being allowed for each man. At the same time, in England, the men slept in beds with two tiers, like the berths in a ship; and not unfrequently, each bed held four men. When it is added, that neither in the West Indies, nor in the home service, was such a thing as an opening for ventilation ever thought of, the state of the air can be imagined.

The means of removal of excreta were, even in our own days, of the rudest description, both at home and in many colonies; and from this cause alone there is no doubt that the great military nations have suffered a loss of men, which, if expressed in money, would have been sufficient to rebuild and purify every barrack they possess.*

SUB-SECTION I.—BARRACKS ON HOME SERVICE.

The imperfection of the English barracks was owing to two causes—first, a great disregard or ignorance of the laws of health; and, secondly, an indisposition on the part of Parliament to vote sums of money for a standing army. At the close of the last, and at the commencement of the present century, the Whig party especially opposed every grant which Mr Pitt brought forward for this purpose.† After the great war, the exhaustion of the nation

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* It is a most remarkable circumstance, that the two diseases which, in the French, Prussian, Hanoverian, and Belgian armies, and probably in the Austrian, and, till lately, in our own army, caused the largest share of the mortality, were a destructive lung disease, termed phthisis in the returns, and typhoid fever.

The production of disorganising lung-disease (though perhaps occurring in several ways) is intimately connected with the constant breathing of an atmosphere vitiated by respiration; and typhoid fever is as closely related with bad drainage. Both diseases are therefore diseases of habitations, and show, in the case of the soldier (who is not subjected to other causes of phthisis, such as inaction, constrained position, and inhalation of dust, &c.), that the air of his dwelling is foul. In hot climates the same rule holds good. Is it not a remarkable fact, that in the West Indies, those islands of paradise, where no cold inclement wind ever vexes the tender lungs, there was, twenty or thirty years ago, an extraordinary mortality from consumption, and from a continued fever, which in all probability was typhoid? Yet who can wonder, when we find, in the Windward and Leeward command, the very best barrack, in 1827, gave only this amount of accommodation; the men slept in hammocks touching each other; the average space allowed to each man measured only 23 inches in breadth; and the total cubic space per head, in this, the best barrack in a tropical climate, was only 250 cubic feet. The air was, of course, putrid in the highest degree.

So also in India, the best writer on the means of preserving the health of troops in India (Dr Chevers) does not hesitate to assert that faulty barracks are, though not the only, yet a great cause of a mortality, which, in a term of years, has been at least fourfold more than at home. Phthisis and typhoid fever hold a subordinate place (though it is not unlikely that their frequency is underrated); but other diseases appear, which are in part connected with faulty barrack arrangements, such as dysentery, and cholera.

In India, as in England, no expense has of late years been spared; but yet the fact remains, that the very habitations erected for their shelter and comfort have proved to the soldiers a source of suffering and death.

† On looking through the Annual Register, I find that Fox, as well as his followers, spoke strongly against the grant of sums of money for improving barracks. Their motives were good,

prevented anything being done, and in spite of the representations of many military men, comparatively little change occurred till the Crimean War. In 1855, a committee,* of which Lord Monck was chairman, was appointed by the War Office to consider this subject, and presented a most excellent Report on Barracks, the suggestions of which have been since gradually carried out. Immediately after this, a Barrack Improvement Commission † was organised, and in 1861 this Commission published a Blue-Book, which not only contained plans and descriptions of the existing barracks and hospitals, but laid down rules for their construction, ventilation, and sewerage, for future guidance. It is difficult to speak too strongly of the excellence of this Report, and if its rules are attended to, there can be no doubt the British army will, as far as habitations are concerned, be lodged in healthier dwellings than almost any class of the community.‡ I must refer to this report for a fuller account of the older barracks and hospitals than can be given here.

Regulations on Barracks.

The Hospital Regulations.—The Director-General is to be consulted on the plans and site of any new barrack.

The Inspector or Deputy-Inspector-General is ordered to see that all regulations for protecting health in barracks are carried out. He makes a monthly inspection, examining into ventilation, warming, lighting, latrines, closets, and all other points.

The regimental medical officer performs the same duties. He is also especially ordered to see that every soldier has a separate bed ;§ that the beds are not placed at a less distance than 6 inches from the wall ; that the beds are aired every morning for at least an hour ; that the windows are opened in the morning as soon as possible, and kept open as far as weather and season will permit. The walls and ceilings are ordered to be limewashed twice a-year.

Each man is allowed 600 cubic feet of space, and the number of men located in each barrack room is to be painted on the door. This is a most important rule, which should be strictly enforced ; if it is not so, it is to be stated in the Annual Report. No regulation is made as to superficial space, and it will vary with the height of the barrack room ; from 56 to 60 square feet is the average.

The Queen's Regulations for the Army order the officer of the day to see to the ventilation and cleanliness of barracks.

Barracks are ordered to be washed once a-week, and no more water is to be used than necessary. On intermediate days the rooms are dry-scrubbed.

Construction of Barracks.

A dry and non-malarious site being chosen, and the subsoil drained, the

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and their jealousy of a standing army justified by what had gone before, but the result has been most unfortunate for the soldier.

* Report of the Official Committee on Barrack Accommodation for the Army ; Blue-Book 1855.

† Mr Sidney Herbert, Drs Sutherland and Burrell, and Captain Galton, were the first Barrack and Hospital Improvement Commissioners. Lord Herbert did not sign the first Report, as he became Minister of War. Dr Burrell retired. The remaining Commissioners (Dr Sutherland and Captain Galton) subsequently published the Report on the Mediterranean Barracks, and, with others hereafter noted, are now occupied with the Indian barracks.

‡ General Report of the Commission appointed for improving the sanitary condition of Barracks and Hospitals, 1861.

§ Formerly two, and even three, men slept together. I have been told, that as late as 1842, one of the old beds, with two tiers, was to be seen at the Guards' barracks in Portman Street, London, though it had, of course, been long disused.

plan of sewerage must be fixed. If, as usual in this country, water is used to carry off the sewage, the medical officer should bestow great pains in considering the plan of the sewers and their ventilation. (See SEWAGE.)

In building the several parts, it is most important to insure perfect dryness of the walls by using courses of slate, vitrified bricks, or asphalte, to prevent water from rising, and to see that the basement rooms are thoroughly ventilated. With regard to the materials for building, the least absorbent substances, whether stone or brick, are to be preferred; the amount of absorption may be tested by placing the brick or piece of stone of known weight and surface into a measured quantity of water, and measuring the water not absorbed in three hours.*

The arrangement of the several buildings must be then considered, and a distinction must be made between infantry and cavalry barracks, on account of the stables in the latter case.

Infantry Barracks.

Block Plan.—Formerly a number of men, even a whole regiment, were aggregated in one large house, and this was often built in the form of a square, the quarters for the officers forming one side, on account of the ease of surveillance. Many officers still prefer this form. But it is always objectionable to have an enclosed mass of air, and if it is adopted the angles should be left open, as recommended by Robert Jackson. The Barrack Improvement Commissioners have very justly recommended that there shall be such division of the men among numerous detached buildings; and instead of the square, that the separate buildings shall be arranged in lines, each building being so placed as to impede as little as possible the movement of air on the buildings, and the accession of the sun's rays.

In arranging the lines, the axis of the buildings should be if possible north and south, so as to allow the sun's rays to fall on both sides. One building should in no case obstruct air and light from another, and each building must be at a sufficient distance from the adjoining house, and this distance should not be less than its own height, and if possible more.

Parts of a Barrack.—1. The barrack room, with non-commissioned officers' rooms screened off. 2. Quarters of the married privates—six to each company. 3. Quarters of the staff-serjeants and serjeants' mess. 4. Quarters of the officers. 5. Kitchens. 6. Ablution rooms. 7. Latrines and urinals. 8. Orderly-room; guard-room. 9. Cells. 10. Tailors' shop and armoury; commissariat stores; canteen. 11. Reading-room (in many barracks); schools; magazine.

It is unnecessary to describe all these buildings.

The old barracks are of all conceivable forms and kinds of construction, for details of which I refer to the Commissioners' Report.

When new barracks are built, the plans of the Commission will be followed.

(a.) Barrack Rooms.—The size and shape of the barrack room will decide the kind of buildings. The Barrack Committee of 1855 recommended that each room should accommodate twelve men, or one squad, as this is most comfortable for the men; but small rooms of this size are more difficult to

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* Bricks imperfectly burned on the outside of the kiln are termed Place, or Samel, or Sandel bricks. They absorb much water. The sun-dried bricks of India are very damp, and absorb water from the air. I am not aware of the absorbing power of the bricks made by compression without burning. Many sandstones are very porous; water beats into them and rises high by capillary attraction. Lime made from chalk absorbs water. Pisé is compressed earth, and, unless covered with cement, is moist.

arrange, and it is now considered best to put twenty-four, or one section, in each room.

The Barrack Improvement Commissioners' recommendations may be condensed as follows :—

The rooms are directed to be narrow, with only two rows of beds, and with opposite windows—one window to every two beds. As each man is allowed 600 cubic feet of space, and as it is strongly recommended that no room shall be lower than 12 feet, the size of a room for 24 men will be—length 60 feet, breadth 20 feet, height 12 feet. This size of room will give 14,400 cubic feet, or (600 × 24) enough for 24 men; but as the men's bodies and furniture take up space, an additional 2 feet has been allowed to the length in some of the new barracks. Assuming the length to be 62 feet, the superficial area for each man will be nearly 52 feet, a little more than 5 feet in the length and 10 in the width of the room. At one end of the room is the door, and a room for the sergeant of the section, which is about 14 feet long, 10 wide, and 12 high. At the other end is a narrow passage leading to an ablution room, one basin being provided for 4 men, and a urinal.

Such is the present arrangement of a single barrack-room, and it is difficult to conceive a better plan, unless it might be suggested that an open verandah, never to be made into a corridor, should be placed on the south or west side. It would be a lounging-place for the men. So also a cleaning-room for arms and accoutrements would be a very useful addition.

The room thus formed may constitute a single hut, but if space is a consideration, two such rooms are directed to be placed in a line, the lavatories being at the free ends. A house of this kind will accommodate half a company. The several houses are separated by an interval of not less than 25 feet. For the sake of economy, however, the houses will in future be frequently made two-storied, so that one house will contain a company in four rooms, and ten will suffice for a regiment.

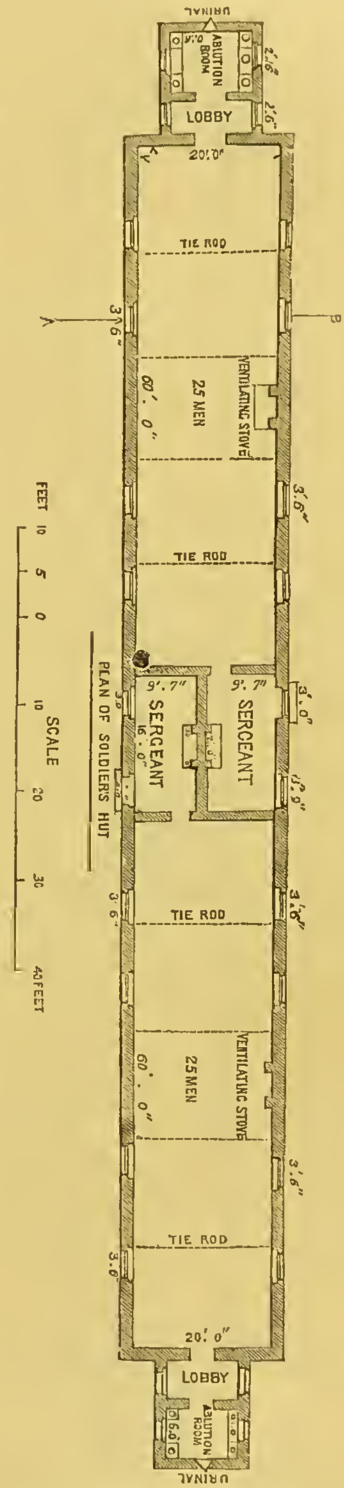

Fig. 76.—Colchester Camp Houses.

The three following plans of recently erected barracks show the arrangements which are adopted. 1*st*, When there is a single story, as at Colchester, and no staircase is required.

2*d*, When there are two stories, and a staircase must be introduced, as in the new cavalry barracks at York.

3*d*, When there are not only staircases, but the barracks must be extended in one long line, including many rooms, and

when, therefore, the ablution rooms cannot be put at the ends of the rooms, but must be placed on the landings, as at Chelsea.

If 10 houses are thus formed, and arranged so as to insure for each the

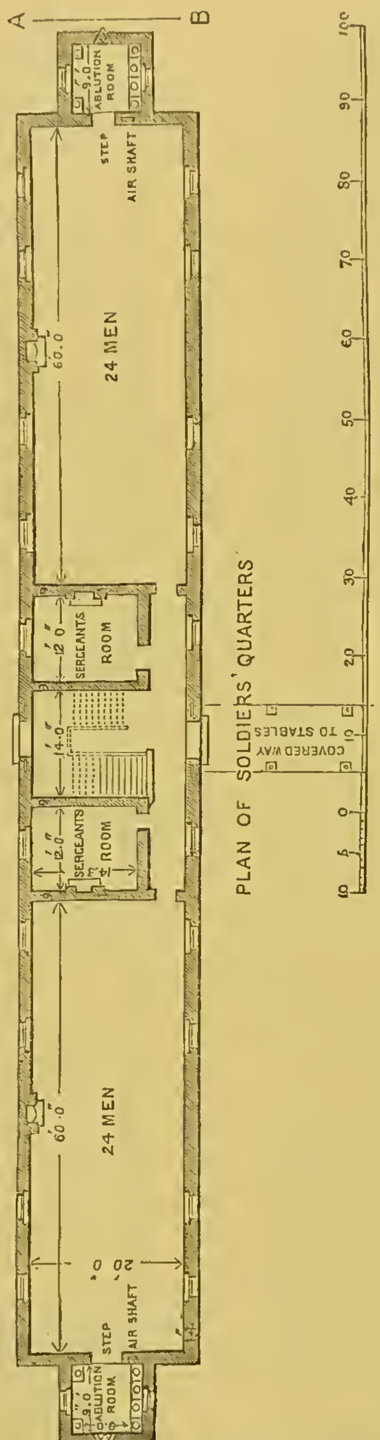

Fig. 77.—New Cavalry Barracks at York.

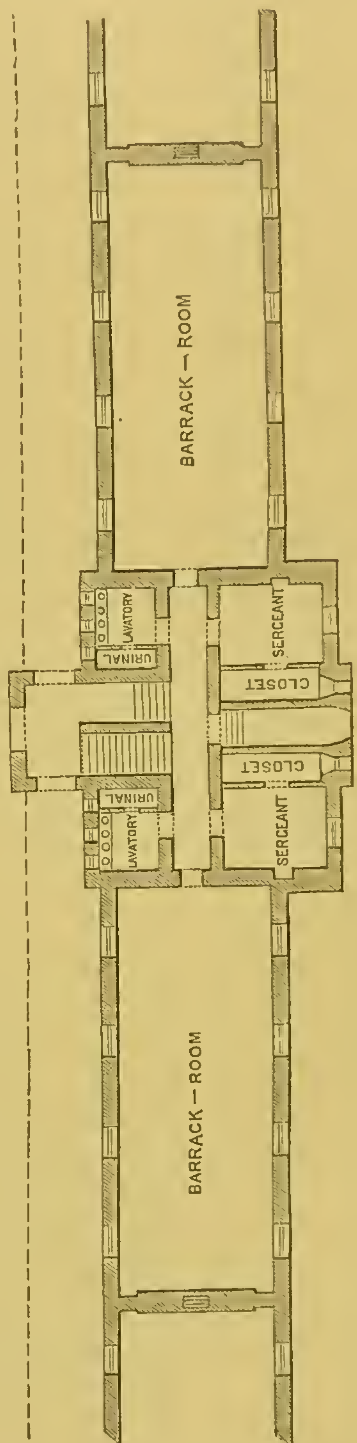

Fig. 78.—New Chelsea Barracks.

greatest amount of light and air, the following area will be occupied by these houses alone. Each house (with walls) would measure about 140 feet long

and 22 broad, and the space between the houses may be taken at 64 feet, or twice the height of the house. The external houses would, of course, have clear spaces on both sides like the others. The area of occupied and unoccupied space would be very nearly 12 square yards to a man.

But this amount of compression, which would be injurious in a large city, will do no harm in these well-planned and ventilated barracks.

(*b.*) *Day-rooms.*—The soldier lives and sleeps in his barrack room; it has long been a desideratum to introduce day-rooms,* but at present the expense is too heavy. Still it is very important that the men should take their meals elsewhere than in their barrack room, and in some barracks a room is provided close to the kitchen. The addition of a few verandahs to the rooms would be less expensive; and if reading-rooms were provided, some of the purposes of day-rooms would be obtained.

(*c.*) *Non-Commissioned Officers' Rooms.*—The Serjeant-major and Quarter-master-serjeant are entitled to two rooms and a kitchen; the Paymaster-serjeant, Hospital-serjeant, Schoolmaster-serjeant, and some others, are entitled to two rooms. The company serjeants have one room each. The rooms are about 14 feet by 12, and 10 high, and contain about 1168 cubic feet when empty. The amount of space is small, and as many of these non-commissioned officers are married, and as it is a matter of justice no less than of policy to make them as comfortable as possible, it is to be hoped that two rooms may be allowed to every married man, and three in the case of all the senior non-commissioned officers. The non-commissioned officers should be looked on in the light of the overlookers of a factory; they are even more essential to the good working of the army than the overlookers are in a mill; but no married overlookers would ever conceive the possibility of living in two rooms, in one of which cooking must be done.

(*d.*) *Married Soldiers' Quarters.*—Seven privates in a company of 100 men are allowed to be married. Formerly they were placed in the men's barracks, a space being screened off, but now they are entitled to separate quarters, each family receiving one room 14 feet by 12, or 168 superficial and 1680 cubic space.

There is no doubt that this allowance of space will be increased in accordance with the general feeling of the time, which is strongly against the mixing up adults and children of all ages in the same room. The amount of space also is really much too small. Certainly two such rooms ought to be given to each married private.

Warming of Barrack Rooms.—The rooms are warmed in two ways—radiant heat from an open fire, and warm air, which is obtained from an air-chamber behind, and heated by the fire. The external air is led by a pipe to this chamber, and then ascending, enters the room by a louvre. The grates are of various sizes, according to the size of the room. Smallest—1 foot 3 inches of fire opening for rooms of 3600 cubic feet. Middle—1 foot 5 inches for rooms of 3600 and 9800 cubic feet. Largest—1 foot 9 inches up to 12,000 cubic feet. Large rooms have two grates. One grate is usually provided for twelve men.

The radiating power of the small barrack grate is aided by a well-arranged angle, and by a fireclay back; as the fire is small, however, the radiating power is not great. The amount and temperature of the air entering in by the warm air louvre has not yet been determined.

* See Report of Committee (1855), p. iv. The objections to day-rooms are—1*st*, More labour to keep clean; 2*d*, Chance of men being debarred from their barrack room during day; 3*d*, Chance of day-room being appropriated on emergencies. The Committee, therefore, recommend only dining-rooms for the men, to be arranged near the kitchen if possible.

In the wards of Fort Pit, with the largest size of grates, the mean rapidity of movement of warm air through the upper slits of the louvre, with a good fire, was found to be about 2½ feet per second, and the total cubic amount of warm air entering per hour through the whole louvre was (approximately) 4600 cubic feet per hour, with a mean temperature of 19° in excess of the external air-temperature. No unusual dryness of the air is produced by the admission of this quantity of warm air, the relative humidity of the air being about 70.

The movement of air through the hot-air louvres is not regular; open doors and windows, which increase the pressure of the air of the room on the louvre, will sometimes delay the movement, and, if the air-chamber is not very hot, will even reverse it and drive the air down; but in cold weather, when the doors and windows are shut, the action is tolerably regular.

Ventilation of Barrack Rooms.—(See page 139).

Ablution Rooms.—Formerly the means for washing were of a very rude kind, but now in the new barracks regular basins with clean water and discharge dirty water-pipes are provided close to every room, in the proportion of one basin to four men. The basins are of slate or iron. In several cases basins on the floor have been provided for feet-washing, and in some instances there are also baths for each regiment. The Barrack Improvement Commissioners recommend one bath to every 100 men. It is understood to be the desire of the Government to provide plunge-baths wherever practicable, and this would not only aid cleanliness, but might be made the means of teaching the men swimming, as suggested by Mr M'Laren.

If water is scarce, the most economical kind of bath is a shower-bath, so arranged as to permit 80 to 100 men to have a bath at once.

Inspections for cleanliness are made in many regiments. They should be systematically carried on under the direction of good non-commissioned officers; but if means are provided, soldiers will generally be cleanly.

Kitchens.—The Barrack Improvement Commissioners have paid great attention to the apparatus for cooking, and have described and figured various plans in their Report. The great object is to cook thoroughly with a small expenditure of coal.*

The opinion of the medical officer will seldom be asked on the question of construction, at any rate on home service. He may, however, be referred to on the question of consumption of fuel, and then he can take as the standard for an ordinary good apparatus ½ ℔ of fuel per man per diem.

More often, however, he will have to examine the cooking, to which reference is made under the different sections in the chapter on Food. The chief points to which attention should be paid, are the temperature, the rapidity of its application, and the ventilation of roasting ovens. Faulty cooking will generally be found to be owing to one or other of these conditions.

Formerly the regimental cooking establishment was badly arranged; men cooked by turns, and for short periods only. Now, cooks are regularly trained at Aldershot.

The other parts of a barrack are—officers' quarters; laundry (in some cases); workshops for tailor, shoemaker, and armourer; orderly-room; guard-room; cells; reading-room (in some cases); chapel and school, which are often in one; magazine; barrack-masters' and quarter-masters' stores for regimental purposes, bread, and meat.

Guard-room.—The guard-room for a regiment of 1000 strong has a size of

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* Count Rumford's standard of fuel was $\frac{1}{13}$th part the weight of the food.—*Barrack Report*, p. 49.

about 24 feet by 18; two rooms open into it—one a lock-up for prisoners, the other a room where prisoners are placed who are not put in the lock-up. In many barracks, however, the lock-up is placed near the cells. The guard-room is ventilated like the other rooms, with Sheringham valves, shafts, &c. M'Kinnell's ventilator is well adapted for it. It should be fitted with a drying closet by the side of the fire, to dry the men's clothes when they come in wet off sentry.

Cells.—The cells are ranged on one or both sides of a corridor. They are 10 feet long, 6½ feet wide, and 9 high (=605 cubic feet), with one window, 2 feet 6 inches wide by 1 foot 3 inches high, placed at the top of the wall, and guarded by iron bars. A movable iron shutter is sometimes added for security, and to make the cell a dark one if needed. Fresh air is admitted through a grating opening from the corridor, which is warmed. The air enters below, or in some cases above; but the former arrangement is the best. A foul-air shaft runs from the top of the room. Two cells are provided for every 100 men. A medical officer inspects the cells every day.

Latrines and Urinals.—Formerly, urine tubs were brought into barrack-rooms every night; and indeed this is still done in some barracks. The tubs are charred inside, are emptied every morning, and filled with water during the day. In all new barracks urinals are introduced; they are placed at the end of the passage beyond the ablution room. It is found by the men that this is inconvenient; the passage is often wet and cold. If the urinal is full of water it splashes; it might be well to put the overflow-pipe a little lower down. It has been recommended to put a small pipe and stopcock a few inches above the urinal, so that the men may cleanse themselves, and in this way possibly lessen the chances of syphilitic infection.

Cesspits are now discontinued in most barracks, and water latrines are used. The latrines are placed at some little distance from the rooms, and are usually connected with them by a covered way; in almost all barracks they are Jenning's or Macfarlane's patents. These are metal or earthenware troughs, which are one-third full of water. Twice a-day a trap-door is lifted, the latrine is flushed, and the soil flows into a sewer or tank at a distance. A hydrant is now frequently placed close to the latrine; an india-rubber pipe can be connected with it, and the seats and floor of the latrine are thoroughly washed in this way twice daily. Probably it would be difficult to suggest anything better than this, although soldiers can be taught to use water-closets like other people, and do not damage them. If water-closets are used, a plan suggested by Mr Williams, C.E., clerk of the works at Gravesend, seems a very good one. It is to have the water-closets at the top of a two-storied building, to the central part of which they form a small third story. In this way the following advantages are secured:—vicinity to the men—under the same roof, yet with perfect ventilation; impossibility of effluvia passing down; proximity to the cistern; and a good fall. At present, however, it seems better to keep to the water latrines outside the barracks.

Cavalry Barracks.

In many cases the men's rooms are placed over the stables, and there has been much discussion as to whether this arrangement is a good one. On the one hand the men get more room, as the horses cannot be crowded, and they are near their horses. On the other hand, there is strong evidence that the effluvia from the stables pass into the men's rooms overhead;* and although

* See especially the evidence of Mr Wilkinson, Principal Veterinary Surgeon to the Army; Report of Barrack Committee (1855), p. 136, question 2262; also, the Report on the Ventilation of Cavalry Stables (1863).

I have been able to find no statistical proof that this has produced sickness among the men, we may safely *a priori* conclude that it is objectionable. The evidence of mews in London is not in point, as they are often close, ill-ventilated courts, independent of the stables in them. Besides, this evidence is as yet rather contradictory.

The question has, however, been solved by a late Report on the Ventilation of Cavalry Stables (1863),* by the Barrack Improvement Commissioners, who have shown that the ventilation and lighting of stables can only be satisfactorily carried out in one-storied buildings, and who, therefore, recommend that the men's rooms shall not be placed over stables.

Stables.—The medical officer has no duties connected with stables, except to see that they are in no way injurious to the health of the men; but it may be well to give the suggestions lately made by the Barrack Improvement Commissioners.

In all the old stables, if it is not already done, ventilating shafts are to be carried up, air-bricks introduced, and more window space to be given.

Whenever stables are to be built in future, it is recommended that the building should be one-storied; that the breadth should be 33 feet; the height of the side walls to the spring, 12; and of the roof, 8½ feet more. The breadth of each stall is to be 5½ feet, and there are only two rows of horses in each stable. Each horse is to have 100 superficial feet, and 1605 cubic feet; the ventilation is by the roof, and is formed by a louvre 16 inches wide, carried from end to end, and giving 4 square feet of ventilating outlet for each horse. A course of air-bricks is carried round at the eaves, giving 1 square foot of inlet to each horse; an air-brick is introduced about 6 inches from the ground in every two stalls. There is a swing window for every stall, and spaces are left below the doors. In this way, and by attention to surface drainage and roof lighting, it is anticipated that stables will become perfectly healthy. Some experiments have been lately made by Dr de Chaumont on the air of some artillery stables at Hilsea. In one stable, with 32 ventilators, and with 655 cubic feet per horse, the CO_2 was 1·053 volumes per 1000; in another, with 1000 cubic feet per horse, and with 420 air-bricks, 25 windows, and a ridge opening, it was ·593 volumes per 1000. The last experiment shows great purity of the air.

Causes of Unhealthiness of Barracks.

These are for the most part obvious enough, and the nature of the prevalent sickness (malarious disease, typhoid fever, lung affection, ophthalmia, &c.), will often give a clue to the detection of the cause. Site, building, air, and water, have all to be carefully examined. The chief causes are—

1. *Defective Site*, viz., giving rise to malaria or damp; or impregnated with excreta or old organic remains; or the building is placed in a position which shelters it too much from the wind, or which, on the other hand, exposes it to too cold or unhealthy winds, &c. (see CHOICE OF SITE.)

2. *Bad Arrangement of Separate Buildings*, if there are more than one, obstructing light; impeding movement of air, &c.

3. *Bad Arrangement of the Parts of the Building.*—Impeding access of sunlight and air; detaining air, or allowing the vitiated air from one part of the building to pass into another.

4. *Ill-Arranged Basements*, allowing damp to rise, or confining masses of damp and semi-stagnant and septic air, which gradually rise into the rooms

* Report of Barrack and Hospital Improvement Commission, signed by Sir Richard Airey, Captain Galton, Dr Sutherland, Dr Logan, and Captain Belfield.

above; or which, from the existence of cesspools, accumulations of filth, ill-arranged sewers, allow contaminated air to enter or collect. Dampness of basements and walls, from bad materials (porous stone or brick), or from want of impermeable courses to hinder damp from rising.

5. *Imperfect Administration and Conservancy*—viz., overcrowding; neglect of proper means of ventilation; want of cleanliness; foul walls, floors, and bedding; short supply of water; bad water; retention of excreta in rooms or under the houses, and bad condition of sewage generally; proximity of ashpits or refuse heaps to rooms, causing contamination of the air, &c.

Reports on Barracks.

The Regulations order the form in which reports on barracks shall be sent in. The arrangement should be strictly followed; it comprehends site, construction, external ventilation, internal ventilation, basements, and administration. It is then certain that no point will be overlooked; and, if nothing can be made out after going thoroughly through all the headings, it may be concluded that the cause of any prevailing sickness must be sought elsewhere. The site and basement should be especially looked at; every cellar should be entered, and the drainage thoroughly investigated. Little can be learned by merely walking through a barrack-room, which is nearly sure to look clean, and may present nothing obviously wrong. With respect to ventilation, the statements of soldiers can seldom be trusted; they are accustomed to vitiated air, and do not perceive its odour. The proper time to examine the air of a room is about 12 to 3 A.M., and the medical officer should, accordingly, visit barrack-rooms between midnight and 3 A.M. every now and then. The cisterns should be regularly inspected.

The walls and floors of the rooms should be carefully looked to. Walls are porous, and often become impregnated with organic matter. If there is any suspicion of this, they should be scraped and then well washed with quicklime. The medical officer should see that the lime is really caustic; chalk and water does little good. Collections of dirt form under the floors sometimes, and a board might be taken up to see if this is the case.

SUB-SECTION II.—BARRACKS IN FORTS AND CITADELS.

In fortified places it is, of course, often impossible to follow the examples of good barracks just given. Citadels may have little ground space; buildings must be compressed, guarded from shot, made with thick and bomb-proof walls, with few openings. Buildings are sometimes underground. Drainage is often difficult or impossible; and if to all these causes of contamination of air we add a deficiency of water, which is common enough, it will not surprise us that the sickness and mortality in forts, in even healthy localities, are greater than should be the case. Both at Malta and Gibraltar there has for years been too large a mortality from typhoid fever, and from the destructive lung disease, which appears in the returns as phthisis.

How these difficulties are to be met is one of the most difficult problems the military engineer has before him. How, without weakening his defences, he is to get light and air into the buildings, and an efficient sewerage, would test the ingenuity of a Brunel. It is possible that the best plan would be by the employment of thick moveable iron doors and shutters. In time of peace these might be open; in time of war easily replaced. But, in addition, means of ventilation must be provided when such defences close the usual openings; tubes must be carried up, and, if necessarily winding, an enlarged area might, perhaps, compensate for this.

It must be said, also, that it is quite certain that in our fortified places many of the arrangements are much worse than they need be, and that the sanitary rules deducible from home experience should be applied in every case when the defensive properties are not interfered with.

Sub-Section III.—Barracks in Hot Climates.*

The older barracks in both the East and West Indies were often merely copies of the English barrack square. In some cases, also, the exigencies of defence led to a cramped and irregular plan, and owing to the little attention which was paid either to the health or comfort of the soldier, overcrowding and deficient ventilation were as common in the tropics as at home. For several years there has been a gradual improvement, and in India especially vast and extensive palaces have been reared in many stations, which testify at any rate to the anxiety of the Government to house their soldiers properly.

It will be desirable to refer here chiefly to the Indian barracks, but the same principles apply to all hot countries.

The Indian Sanitary Commission have lately recommended that each man in barracks shall have 100 superficial feet, and 1500 cubic feet. The Government of India recommended in 1864 that there should be 90 superficial feet in the plains, and 77 in the hills, which, with a width of 24 and 22 feet, and height of 20 and 18 feet, would give 1800 cubic feet in the plains and 1408 in the hills. Mr Webb,† who has paid great attention to the subject of overcrowding in Indian barracks, and who believes that it is the grand cause of insalubrity in India, has adduced good reasons for thinking that this amount is not nearly sufficient. It is suggested, indeed, that 3000 cubic feet of space is not too much.

I shall not refer to the old barracks, but to the later and the present patterns.

In 1857 and 1858 the Bengal Government ordered standard plans to be prepared, and some barracks have been built in accordance with them. A description and figures will be found in the former editions of this work. In 1863 the Governor-General of India in Council ordered a renewed inquiry into the matter, and Colonel Crommelin submitted altered designs for barracks, which were subsequently submitted to the Bengal, Madras, and Bombay Governments, and to the Army Sanitary Committee at home. The plan of these new barracks is essentially that proposed by the Indian Sanitary Commission; while the preparation of the detailed design is left to the local officers, certain general principles are strictly laid down, and standard plans suitable for different localities are furnished for guidance. The number of men to be placed under one roof is fixed at 40 or 50 (half company barracks), except under exceptional circumstances; the number of men in one room is to be 16 to 20, and not to exceed 24; the barracks are to be two-storied (the lower rooms being used as day-rooms) in the plains, and one or two storied in the hills, both floors being used for dormitories. If ground is restricted, three stories may be erected, the lower being used as a day-room; single verandahs of 10 or 12 feet wide surround these rooms. There are to be only two rows of beds in the dormitories; the beds are to be 9 inches from the

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* The Barrack and Hospital Improvement Commission, consisting of Sir Richard Airey, Captain Galton, R.E., Dr Sutherland, Dr Logan, Captain Belfield, with Colonel Sir Proby Cautley, Sir Ranald Martin, and Mr Rawlinson added for Indian Sanitary Works, have drawn up a Report, entitled "Suggestions in regard to Sanitary Works required for improving Indian Stations," which will become the official guide to such works in India.

† Remarks on the Health of European Soldiers in India. By H. Webb. Bombay, 1864, p. 50.

wall, and only two beds are to be in the wall space between two contiguous doors (or windows); in the plains each bed is to have $7\frac{1}{2}$ feet of running wall space, in the hills 7. The day-room accommodation is to be about 45 square feet per head. The general arrangements of the building are based on the suggestions of the Royal Indian Sanitary Commission. If the lower story is not used as a day-room, a mess-room is placed in the centre; a dormitory, separated by serjeants' quarters, being on each side of it; at each end of the dormitory are closets and night urinals; and what appears to be the best plan places these at the extreme end of the verandah, leaving space between them and the dormitory.

The married people's quarters are to be grouped in small one-storied blocks, each block holding the married people of a company or troop. Two rooms (16 feet × 14 feet and 14 feet × 10 feet) are provided for each family; verandahs, 12 and 10 feet wide, are provided.

In all these arrangements it will be perceived that the essential principles of the home barracks are preserved; long, thin, narrow lines of buildings, with thorough cross ventilation, with the sleeping-rooms raised well off the ground, would certainly appear to be as good an arrangement as could be devised. A few more remarks on some of the points have to be made.

It has been proposed to adopt a different style of building altogether, and to copy some of the sub-tropical nations, who build their towns with narrow streets; and so arrange their houses as to have as much shade as possible. But this impedes ventilation; and the same result is obtained by observing the rule of never allowing the sun's rays to fall on the main wall of a house.

1. *Size of Houses.*—If there are no strong military reasons to the contrary, it seems certain that it is even more important in India than in England to spread the men over the widest available area, and not to place more than fifty men in a single block, and twenty-five men in a single room; and, therefore, the proposed plan is most desirable. There has been an objection raised, that small detached houses on the hot plains of India, not having any large space in shadow, get everywhere heated by the sun's rays, and become very hot. The objection is theoretical; it is the immense blocks of masonry used in the construction of large buildings which are to be avoided as much as possible, since, when once heated, they take hours to cool.

2. *Arrangement of Houses.*—Broadside on to the prevalent wind, and disposition *en échelon*, as now adopted in India, is obviously the proper plan. The only exception will be when there are marsh or gully winds to be avoided, and then the houses should be placed end on to the deleterious wind; and no windows should open on that side. But it is seldom such a site would be selected or kept.

If a barrack is built on a slope, and the ground is terraced, the Army Sanitary Committee have recommended that the barrack should be placed end on to the side of the hill, and not nearer the slope than 20 to 30 feet. But terracing should be avoided as much as possible.

3. *Breadth of Houses.*—As in England, it is important to have only two rows of beds in each house, and to keep the houses under 30 feet in width, so as to permit effective perflation. A single verandah is as good as a double one in keeping off the direct rays of the sun from the walls of the house, and two verandahs (one inner, and one outer) add to the breadth to be ventilated. The width of the verandahs must be 10 to 12 feet; and on the southern and western sides wooden jalousies may have to be placed, so as to occupy 3 or 4 feet at the upper part of the verandah.

Verandahs should be ventilated by openings at the highest part, so as to

have a free movement of air through them; this is very important. If there are two stories, the roof of the upper verandah should be double.

Materials of Building.—On this point there is little choice, for the risk of fire renders the use of wood undesirable for walls and roof. And yet, apart from this risk, loosely joined wood, or frames of bamboo, have the great advantage of allowing air to pass through the walls. Brick or stone has therefore to be used. In India, sun-dried brick (*kutcha*), covered with cement, or faced with burnt brick, is often used; and the remains of Babylon or Nineveh show how imperishable a material this is if properly protected. It is said to be a cooler material than burnt brick (*pucka*), but it absorbs a great deal of moisture.

Iron barracks were sent out from England during the mutiny, but were said to be hot, and were not liked; but iron frames have been usefully employed, the intervals being filled up with unburnt bricks. There is, however, a very general feeling against unburnt brick, on account of the moisture it absorbs and retains. The concrete walls now coming into so much use in England would be particularly adapted for India; they are cheap, and very dry.

Construction of the Building.—The three points to be aimed at are: avoiding the malaria and dampness of the ground, should there be any risk of this; insuring coolness; providing ventilation.

(*a.*) *Employment of Open Arches for the Basement.*—The extraordinary diminution in the risk of malaria by elevating the building only a few feet above the ground, and allowing a free current of air under the house, is illustrated in various parts of the world: along the banks of the Lower Danube, in the plains of Burmah and Siam, &c. But another great benefit is obtained: dryness and freedom from pent-up, stagnant, and often septic masses of air are insured, so that, even when the soil is not distinctly malarious, buildings should be raised. In a malarious country, the height of the ground-floor above the ground should be 8 or 10 feet; in non-malarious districts 3 or 4 feet are sufficient, but it should always be high enough to allow cleaning.

If high enough, these open spaces afford excellent places for exercise during the heat of the sun.

(*b.*) *Walls.*—Very thick brick walls do not add to coolness (Chevers), but being thoroughly heated during the day, give out heat all night. The direct rays of the sun should not be allowed to fall on any part of the main wall. This will be found one of the most important rules for insuring coolness. Double main walls, with a wide space between, and free openings above and below, so as to admit a constant movement of air between, is the coolest plan known. Considering the excellent ventilation which goes on in bamboo and wooden houses, it may be a question whether, in the warm parts of India, the walls might not be made as far as possible permeable; at any rate, above the heads of the men. Whitening the outside walls reflects the heat, but is dazzling to the eyes; almost as good reflection, and much less dazzling, is obtained by using a slight amount of yellow or light blue colour in the cement or lime-wash.

(*c.*) *Floors.*—The materials at present used are flagstones (in Bengal), slates (in some barracks in the Punjab), greenstone (in some Madras barracks), tiles, bricks placed on end and covered with concrete, pounded brick and lime beaten into a solid concrete and plastered with lime, broken nodulated limestone or kunkur (in places where the masses of kunkur are found, as in Bengal), asphalt, pitch, and sand, wood (Chevers). Of these various materials, the asphalt gets soft and is objectionable; the cements and kunkur wear into holes, produce dust, and have been supposed to cause ophthalmia (Chevers); wood is liable to attacks of white ants, &c.

On the whole, it would seem that good wood (if there be a space below the barracks) with brick supports is the best, and after this tiles.

(*d.*) *Roofs.*—Double roofs are now usually employed, and are made slanting, and not terraced. The terraced roofs, if made single (*i.e.*, with battens on the joists covered with kunkur), conduct heat too freely; but if made double, with a good current of air, there is an advantage in giving a promenade to the men, and also, at some seasons of the year, the roof may be most advantageously used as a sleeping-place.

The sloping roofs are better adapted for ventilation. The coolest roof is made of thatch, covered with tiles; it would be cooler still if the thatch were outside; but thatch is dangerous on account of fire, and harbours vermin and insects. If there is a good space between the two roofs (2 feet), and if there are sufficient openings to permit a good current of air, perhaps two tile roofs would be as cool as any.

It has been suggested by Julius Jeffries to have the outer roof made of a polished metal (tin), to reflect the heat. In Canada tin is used. In the Crimean War the roofs of Renkioi Hospital, on the Dardanelles, were covered with polished tin; it was found, however, somewhat difficult to place it so as to exclude rain, and the surface soon became tarnished. The thermometric experiments did not show a greater lessening of heat than 3° Fahr. below houses not tin coated.

(*e.*) *Doors and Windows.*—These are now always made very numerous, and opposite each other, so as to permit perfect perflation. The official "Suggestions" order one window for every two beds. Five doors are recommended for each room of twenty-five men; and Norman Chevers gives a good rule: A light placed in the centre at night should be seen on all sides. Upper as well as lower windows—a clerestory, in fact—are useful; the lower windows should then open to the ground. In most of the stations in northern India the windows must be glazed.

The committee appointed to carry out the suggestions of the Indian Sanitary Commission have recommended that each window should consist of two parts—the upper portion, about 2 feet in depth, being hinged on its lower edge to fall inwards, so as to direct the currents of air towards the ceiling of the room.

Ventilation of Tropical and Subtropical Barracks.

If barracks are not made too broad, and are properly placed, the same principles of ventilation may be applied to them as to barracks at home. The perflation of the wind should be obtained as freely as possible. The numerous doors and windows, however, render it unnecessary to provide special inlets; outlets should, as at home, be at the top of the room, either along the ridge, or if of shafts, they should be carried up some distance; if they are made of masonry, and painted black, the sun's rays will cause a good up-current. The area of the shafts is ordered ("Suggestions," p. 22) to be 1 square inch to every 15 or 20 cubic feet, with louvres above and inverted louvres below. In the lower rooms these shafts are to be built in the walls; in the upper rooms to be in the centre.

In many parts of India, however, at particular times of the year, the air is both hot and stagnant; in such stations artificial ventilation must be employed, and the forcing in of air offers greater advantages than the method by aspiration. The wheel of Desaguliers was introduced into India many years ago by Dr Rankine, and, under the name of "Thermantidote," is frequently used in private houses and hospitals. Wheels may be used of a larger kind, and driven by horses or bullocks, or steam or water power. The

great advantage is that the air can be taken through a tunnel, and cooled either by the cooler earth or by evaporation (see Cooling of Air).

An Arnott's pump, made as large as a man can easily work, will be found to be cheaper, and as good as the thermantidote.

The common punkah is a ventilator, as it displaces masses of air; the waves pass far beyond the building, and are replaced by fresh waves entering in. An improved punkah, worked by horse or bullock, and supplied with water for evaporation, was devised by the late Mr Moorsom of the 52d Regiment; it is described and figured in the Report of the Indian Sanitary Commission, and would seem likely to be a very useful modification of the common punkah.

Ventilation in most parts of India must be combined with plans for cooling, and often for moistening the air.

Cooling of Air.—When the air is dry, *i.e.*, when the relative humidity is low, there is no difficulty in cooling the air to almost any extent. If the air be moving, this is still easier. The evaporation of water is the great cooling agency. A drop of water, in evaporating, absorbs as much heat as would raise 967 equal drops 1° Fahr., or in other words, the evaporation of a gallon of water absorbs as much heat from the air as would raise $4\frac{1}{2}$ gallons of water from zero to the boiling point. As the specific heat of an equal weight of air is $\frac{1}{4}$ that of water, it follows that the evaporation of 1 gallon or 10 ℔ of water will cool ($10 \times 4 \times 967$) 38,680 ℔ of air, or 477,637 cubic feet of air 1° Fahr.; or, to put it in another way, the evaporation of 1 gallon of water will reduce 26,216 cubic feet of air from 80° to 60° Fahr. In India the temperature of a hot, dry wind is often reduced 15° to 20° by blowing through a wet kuskus tattie; but merely sprinkling water on the floors will have a perceptible effect on the temperature.

When the air is stagnant cooling is less easy. In India it is often attempted, in a still atmosphere, to insure coolness by creating currents of air either by the simple punkah or by thermantidotes; these act by increasing evaporation from the body, and they certainly do away with the oppressiveness of a still atmosphere. But evaporation of water must be also employed, as in Captain Moorsom's punkah just referred to, or in some other way.

In the case of a thermantidote, or Arnott pump, thin, wet cloths suspended in a short discharge-tube, or ice suspended in it, or a bottle containing a freezing mixture, and with a wet surface, will answer equally well.

When water is abundant other contrivances may be employed. A little instrument is now used in medicine, by means of which water is subjected to great pressure by means of a pump which compresses air in a globe. When a stopcock is turned, the water is forced out with such velocity as to be converted into the finest spray. It is, so to speak, pulverised. Now, nothing could be better adapted for evaporation and coolness than to interpose, in the way of a dry current of air, water thus finely divided. Or the beautiful sheet water fountains used to wash air for ventilation might be employed. In the old Roman, and some Italian houses, coolness was obtained by a fountain in the central court; and where it can be done, the more common employment of fountains in the houses in the hot parts of India may be suggested.

Cooling is then easy when the air is dry, or is not moister than 70 per cent. of saturation; but when the air is very moist, and almost saturated, as is often the case, for example, in Lower Scinde, and is at the same time still, evaporation is very slow. What can be done? Of course the air must be set in motion by mechanical means. But how is it to be cooled? Two plans suggest themselves—taking the air through a deep tunnel, and the employment of ice.

The tunnel plan was tried, I believe, some years ago at Agra, and was not well thought of. But everything depends on the mode of making the tunnel. It must be deep enough to get into a cold stratum of earth.

The Chinese, in the north of China, suspend lumps of ice in their rooms during the summer; but this seems a wasteful plan. Ice in tunnels would have a much greater effect. If the ice cannot be obtained, freezing mixtures might possibly be used, if the expense is not a bar.

Ablution Rooms.—In India, every private house, and almost every room in a house, belonging to a European, has its bath-room. And not only the luxury, but the benefit is so great, that bath-rooms should be considered essential to every barrack. For the usual purposes of ablution the plan now used on home service is the best; but it should be supplemented by shower-baths. In order that these shall be efficiently given, the old plan of carrying water by hand must be given up; shower-baths for a regiment could never be provided in this way; water in large quantity must be laid on in pipes, and cisterns at the top of every barrack should feed the ablution rooms, and supply water for the urinals. At least from 12 to 18 gallons daily should be allowed per head for shower-baths alone, and, if possible, more than this, as general baths should be also provided. So essential must baths be considered for health, that a large supply of water should be considered a necessary condition in the choice of site. The disposal of the water after use is a question for the engineer; but it must not be permitted to soak into the ground near the barracks; it might seem superfluous to notice this, if the custom of allowing the ablution water to run under the houses did not prevail at some stations.

Urinals.—Urine tubs are still used in many of the barracks in India, but their use should be discontinued as soon as possible. Evaporation is rapid, and decomposition soon sets in. Several army surgeons have pointed out that the atmosphere is greatly contaminated in this way, and some have considered that affections of the eyes are produced by the ammoniacal fumes. Earthenware or slate urinals should be used, with water running through them; and if there are no drains to carry off the urine, a zinc pipe may be laid inside the building, and open into a tub below, which should be emptied daily.

The War-office Committee, in their "Suggestions" (p. 24), recommended Mr Jenning's urinal, which consists of a basin, valve, and syphon-trap, supplied with water. It is cleaned and filled by raising the handle. As already noticed in the Home Barracks, the suggestion of a small water-tap above, to allow the means of ablution, seems an excellent one.

SECTION II.

WOODEN HUTS.

Of late years the use of wooden huts, both in peace and war, has greatly extended in several of the European armies. In peace, their first cost is small, and they are very healthy. In war, they afford the means of housing an army expeditiously, and are better adapted for winter quarters than tents.

The healthiness of wooden huts doubtless depends on the free ventilation; when single-cased, the wind blows through them; and even when double-cased, there is generally good roof and gable ventilation.

Numerous patterns of huts have been used in our own and other armies, from small houses holding six men to the large houses designed by Mr Brunel for Renkioi Hospital, and which were 25 feet high in the centre, 12 feet at

the eaves, and hold 50 men. In the Crimea the most usual sizes were for 12, 18, and 24 men.

In arranging lines of huts, as much external ventilation and sunlight must be secured as possible for every hut. According to circumstances, the arrangement in lines, or *en échelon*, &c., must be adopted.

In time of peace huts are sure to be put up well; to be properly underpinned; on a drained site, and well warmed.

War Huts.

In the putting up of huts in time of war, when everything is done more roughly, the following points should be attended to:—

Do not excavate ground, if possible; and never pile earth against the sides.

(*a.*) *Floor.*—Whenever practicable, underpin the joists, so as to get a current of air under the floor. Arrange for the drainage underneath, so that water may not lie underneath, but may be carried by a surface drain at once to an outside drain. If the floor is entirely of wood, have it screwed, and not nailed down, so that the boards may be taken up, and the space below cleaned. If the sides are of planks, and the centre of earth, pave the centre with small stones, if they can be got, so that it may be swept. If this cannot be done, remove a little of the surface earth every now and then, and put clean sand or gravel down.

(*b.*) *Sides.*—If the sides are double, leave out a plank at the bottom of the outside, and at the top of the inner lining. If the sides are single, make oblique openings for ventilation above the men's heads, with wooden flaps falling inwards, and capable of being pulled more or less up, and enclosing the opening. Place a plank obliquely along the bottom at the outside, to throw the drip from the roof outwards, so that the water may not sink under the houses. Whitewash both the inside and outside of the planks.

(*c.*) *Roof.*—Arrange for ridge ventilation. If felt is used, let the strips run along the sides, and not over the ridge, and beginning at the bottom, so that each successive strip may imbricate over the one below it; use no nails, but place thin strips of board across the strips from the ridge downwards, to hold the felt down.

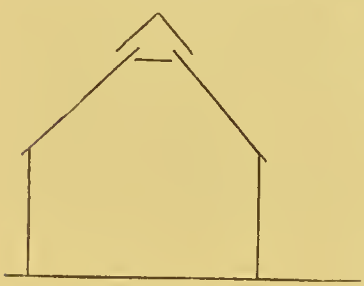

Fig. 79.

Warming.—In cold countries, if stoves are provided, place them at one end, and let the chimney run horizontally along above the tie-beams, to the other end, and open at the gable; in this way, the heat is economised: or put a casing of wood round the stove, except in front, and allow fresh air to pass between the stove and casing. If no stoves are provided, and a fire-place is made with stone, it should be put at one end, and a wooden trough running out at the gable be used as a chimney. If a good broad slab of stone can be obtained for a hearth-stone, dig a trench under the boards and lead the air from outside under the hearth-stone, and provide an opening at the other side of the stone. In this way the entering air is warmed.

Trenches should be carried round huts as in the case of tents.

Causes of Unhealthiness of Wooden Huts.

1. *Dampness from Ground, Earth against Walls, &c.*—Drain well. Cut away ground from outside; have good trenches round, with a good fall.

2. *Substances collecting under Floors.*—Look well to this as a common cause of unhealthiness.

3. *Earth round Huts saturated with Refuse, Urine, &c.*—Every now and then clear away the surface earth, and replace it with clean dry earth.

4. *Ventilation* bad from too few openings.

5. *Cold.*—Issue extra clothes, if additional fuel cannot be obtained. See that the greatest effect is obtained from the fuel; but do not, if it can possibly be helped, close the ventilators.

SECTION III.

TENTS AND CAMPS.

Sub-Section 1.—Tents.

In temperate climates no army has ever been able to war without tents; and the importance of providing good tents is obvious.

A good tent should be light, so that it may be easily transported, readily and firmly pitched, and easily taken down. It should completely protect from weather, be well ventilated, and durable.

It is perfectly easy to devise a tent with some of these characteristics, but not to combine them all.

The tents used in our army are as follows:—

Home Service.

The Bell-Tent.—A round tent with sides straight to 1 or 2 feet high, and then slanting to a central pole. Diameter of base, 14 feet; height, 10 feet; area of base, 154 square feet; cubic space, 513 feet; weight, when dry,* about 65 to 70 ℔. The canvas of the new pattern is made of cotton or linen. The ropes extend about 1½ foot all around. It holds from twelve to sixteen men; and in war time, even eighteen have been in one tent. The men lie with their feet towards the pole, their heads to the canvas. With eighteen men, the men's shoulders touch. Formerly, there was no attempt at ventilation; but now a few holes are made in the canvas near the pole. Ventilation, however, is most imperfect.† Dr Fyffe (of the Army Medical School), who has carefully examined this point, finds the holes so small, that the movement of air is almost imperceptible. There is little ventilation through the canvas, and none at all when it is wet with dew. The bell-tent is in all respects, except weight, a rude and imperfect contrivance. It becomes excessively hot; and the atmosphere in the middle of the day is most oppressive. When pitched, as usual, without any persons in it, the air in a few hours loses its freshness, and is close and unpleasant when the tent is entered.

The Hospital Marquee.—An improved hospital marquee was issued in 1866. It is in principle the same as the old marquee, but with improved ventilation. This tent is two-poled, with double canvas. It is made of a lower, almost quadrangular part, and an upper part, sloping from the top of the straight portion to the ridge. Length, 33 feet; breadth, 12 feet (up to 5 feet in height, and lessening above); height, 5 feet to the top of the straight part, and 7 from this to the ridge, making 12 from ground to ridge; area of ground, 396 square feet; total cubical space (reckoning the lower part as a quadrangle, and the upper part as a triangle), 3366 feet.‡

It is intended for sick, and can accommodate ten men well; eighteen is the regulation, and twenty-four men have been put in it; but this crowds it

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* Complete wetting of a tent adds from 30 to 40 per cent. to the weight.

† Barrack Improvement Report, p. 170.

‡ This measurement of superficial and cubic feet is that of the older pattern; the new pattern is a little less.

extremely. There are ventilators, and a large flap at the top can also be opened for ventilation, and the fly can be raised. Its weight (including the valise) is about 500 lb. An india-rubber sheet is now supplied, to put on the ground, and this weighs 145 lb.

It is a good tent when care is taken with ventilation; but there should be a way of raising one whole side, so as to expose every part of the tent; and if the height of the upright part were 6 feet, it would be more convenient.

Shelter Tent.—There is no official shelter tent for the English army on home service, but one was lately issued for service at the Cape. Each man carries a canvas sheet, made up of a quadrangular (5 feet 9 inches × 5 feet 3 inches) and of a triangular piece (2 feet 8 inches height of triangle × 5 feet 3 inches base). Buttons and button-holes are sewn along three sides, and a stick (4 feet long, and divided in the middle) and three tent pegs and rope also are provided. Two or four of these sheets can be put together, the triangles forming the end flaps. A very roomy and comfortable shelter tent, 4 feet in height, is formed, which will, with a little crowding, accommodate six men, so that two sheets can go on the ground. The objection to this tent is its weight, viz., 6 lb 14 ounces per man. If a thinner material could be obtained, and if the size could be a little lessened in all directions, it would be a very good tent. It is in principle, and even in detail, very like the tent proposed by Corporal Paul, of the 12th Regiment, and noticed in page 324.

Officers' Tents.—Small and large marquees are allowed. Each field-officer, and captain, and every two subalterns, have one tent.

On Indian Service.

The tents for Europeans are marquees, with two poles and ridge, double fly. Length, 21 feet; breadth, 15; height to inner fly, 10 feet 3 inches; and outer fly, 11 feet 9 inches. Twenty-five infantry are accommodated with 85 cubic feet per man; or twenty cavalry with saddles, with 100 cubic feet.

The tents for natives have a single fly. Length, 22 feet; breadth, 12; height of pole, 10 feet; to accommodate twenty cavalry, or twenty-five infantry.

French Tents.—In the French army, two chief kinds of soldiers' tents are used.

1. The *tente d'abri*, or shelter-tent of hempen canvas, is intended for three or four men. Each man carries one-third or one-fourth of the tent, and a stick; the weight of the two being 3 lb. The canvas he carries serves him for a covering while marching; or he can form it into a bag, into which he can creep. Each sheet is 5 feet 8 inches long, and 5 feet 3 inches broad; the stick is 4 feet 4 inches long, and $1\frac{1}{2}$ inch in diameter. When the tent is pitched, the three men can creep inside, and have as much space and as good ventilation as the English soldier in the bell-tent. This sort of tent has the great advantage of giving protection during the march, and immediate cover when the march is over. The number of baggage animals for the army is also greatly lessened.

Some of the French *tentes d'abri* are intended for four or six men; the length is $6\frac{1}{2}$ feet, the height, $3\frac{1}{4}$; it is carried by three or four men. The total weight of the tent is from $6\frac{1}{2}$ to $8\frac{3}{4}$ lb.

2. *Tente de Troupe.*—This is a two-poled tent, with a connecting ridge-pole. It is $19\frac{1}{2}$ feet long, by 13 or 14 wide, and 10 high; the ground area is 253·5 square feet. It is intended for sixteen men. There are two openings in the centre, which can be held out by poles, each 5 feet in length, or closed at pleasure. Between the poles, at the height of 6 feet, there is a perforated

wooden plank, on which articles are placed, or from which they hang. The total weight is 143·5 lb avoir.

3. Two conical tents are also sometimes used, like the English bell-tent; one (*tente conique*) a cone, and the other having an upright wall 16 inches high, and then being conical above (*tente conique à muraille*). This last tent is ventilated at the top; a galvanised iron ring, 12 inches in diameter, receives the canvas, which is sewed round it. An opening is thus left of 113 square inches, which can be closed by a wooden top which rests on the top of the pole, and is buckled to the ring. Each tent holds twenty men.

Prussian Tent.—This is a conical tent, with a single pole, like the bell-tent of the English army; it is 14 to 15 feet diameter, the pole 11⅔ feet high; it holds fifteen to eighteen men, and weighs 80 lb avoir.

Prussian Hospital Tent.—The ground-floor of the tent is a rectangle 62 feet long and 24 broad; the tent is 16 feet high; there are 6 or 8 poles; the area is 1488 square feet. It is divided into three parts: a central, 52 feet long and 24 broad (= 1248 square feet), for the sick, and two rooms, each 5 feet long and 24 broad, for attendants, utensils, &c. Some of the tents are made with hollow iron poles, and there is a good hood for ventilation. Each tent could contain 20 to 22 beds, but only 12 patients are placed in it. It stands on an area of 80 feet by 40. Since 1862 the Prussians have treated many of the worst cases under such tents during the summer. The same practice has been adopted in the Austrian army for twelve years past.

The Prussian hospital tent appears to be excellent, and superior to the English marquee.

*Russian Tent.**—The infantry tent is quadrangular, 14 feet square and 7 feet high to the slope; there is a centre pole and four corner poles; it is intended for fourteen men, but only twelve are usually placed in it. Round the tent is a bench 1½ foot broad, and covered with straw mattresses and sheets (in the summer camps) for sleeping. A wooden rack round the centre pillar receives the rifles. The canvas can be partly or entirely lifted up. The officers' tents have double canvas.

Northern American Tents.—At the commencement of the civil war the Sibley tent was much used. It is conical, 18 feet in diameter, and 13 feet high, with an opening for ventilation, and gives 1102 cubic feet; often twenty or twenty-two men were held by one tent. Bell and wedge-shaped tents were also used; the latter was 6 feet 10 inches long, 8 feet 4 inches broad, and 6 feet 10 inches high, with a cubic space of 194 feet. It held six men.

These tents, however, did not answer; the ventilation was most imperfect, and in the summer of 1862 ponchos and shelter-tents were issued, which in the army of the Potomac superseded the old tents.† The poncho is a piece of oilcloth with a slit in the centre, through which the head is put; two ponchos can form a shelter-tent. The army of the Potomac spent the winter in improvised huts of logs or mud, with the shelter-tent for the roof.

The larger tents are, however, still used for stationary commands, and for hospital purposes.

Other Plans.—A very great number of different kinds of tents are employed by different nations, and many plans have been proposed of late years.‡ Of these Edington's square military tent, and Turner's and Rhodes' tents, are the best. The first is a single-poled pyramidal tent, with a second pole to sustain the entrance flap; it is 13 feet square, and will hold sixteen men.

* From Heyfelder's Camp of Krasnoe-Selo, 1868.

† Woodward, "Outlines of the Chief Camp Diseases of the United States Army," 1863, p. 46.

‡ A very good description will be found in Major Rhodes' "Tent Life and Encamping," 1859.

There are ventilating holes through the canvas at the top, protected by canvas. It weighs 90 lb.

Turner's tents are conical and oblong; the pole is hollow iron, and is supported in a tripod, below which a stove can be placed, to which the pole serves as a chimney. Instead of ropes, galvanised wire and iron pegs are used, and wire ropes running from the pole to the circumference are used to sustain hammocks, and so raise the men from the ground. A tent for eighteen men weighs 300 lb. Turner's hospital tent is 60 feet long, 29 wide, and 18 high, and weighs 896 lb.* A great advantage of these and similar tents is that a stove can be easily used, and there is pretty good ventilation through the hollow pole. The raising the men off the ground is also a great advantage.

Major Rhodes' tent is a curvilinear octagon, which is made up by a frame of stout ash or bamboo ribs, which are stuck into the ground, passing through a double-twisted rope near the ground, and bent into the centre, where they meet in a wooden head fitted with iron sockets, to receive the ends of the ribs. The framework is not unlike an open umbrella. The rope through which the ribs pass is well pegged to the ground, and there are also outside storm ropes, so that, both from the shape of the tent and its ties, no storm can blow it over. There is a good top ventilation through an opening protected by a leathern cap, and the canvas covering which contains the tent (when packed) can be divided into two parts, and buttoned inside the bottom of the tent, so as to prevent air from blowing in under the canvas.

A small tent (guard tent), capable of holding four or five men, is also used. The hospital tent is made of two of these tents connected by a portion of tent made of ribs which run to a ridge pole. It is 30 feet long, 15 feet wide, and 10 feet high, but can be made of any length. The field tent weighs 100 lb; the hospital tent, 395 lb. Both these seem excellent tents; they give much more ground area, cubic space, and standing room, than any form of cone tent, and are more convenient, as there are no poles.

General Conclusions.

The history of all wars in the temperate zone proves that men cannot war without tents. Both theory and experience show that the best arrangement for a soldier is that he should carry a portion of a shelter-tent, which may at once serve him for a cloak on the march, and a cover at night, if he is obliged to lie out without pitching his tent, and which, joined to two or three other similar pieces, may make a tent to hold three or four. For camps of position, where troops are kept for months, and where there is less trouble about transport, larger tents can be used, and then either a tent like that of Major Rhodes', or a two or four poled tent like the Prussian, appears to be the best.

The French system, now adopted by the Americans, is in reality a very old one. The Macedonians used small tents which held two men,† and Rhodes figures a little shelter-tent of the same form as the French, and holding apparently five men, which was in use in the British army in 1750.

At various times in late wars the English army have extemporised tents of this description, by suspending blankets over their firelocks. An instance of this occurred in the long march of the 12th Regiment, in 1852, at the Cape (see chapter on MARCHES.) Profiting by this hint, and struck by the military advantages which would result from the men carrying their tents, a private

* Rhodes, p. 178.

† Rhodes' "Tent Life," p. 13.

soldier, Paul, of the 12th Regiment, devised a shelter-tent for three men, which was shown at Chatham in 1862. It is an improvement over the French tent, and is better than the American poncho-tent, as, instead of a slit, through which the head passes on the march, a portion of the sheet goes over the head so as to form a hood. The man is thus perfectly protected on the march to below the knees. Two sheets form a tent for three men, the third sheet being on the ground. Colonel Stewart of the 2d Depot Battalion has still further improved this tent, which now seems as good as it can be.

On the whole, this tent seems better than Major Rhodes' guard-tent, as one or two men can form a tent with their own canvas; and if the sticks are lost, the rifles can supply their place.

An army could then encamp and house itself as fast as it could take up its ground, and so short is the time necessary for pitching the tent, that even in heavy rain the men would not get wet. The men lie much more comfortably than in the bell-tent,* and there is scarcely a possibility of its being blown down.

Sub-Section II.—Encampments.

Several regulations have been issued by the Quartermaster-General's Department; and the Queen's Regulations (pocket edition, section 16), contain several orders which will be noticed hereafter. The Barrack Improvement Commissioners also, in their Report (1861, p. 168), lay down certain rules which must be attended to.

Encampments are divided into two kinds—those of position, which are intended to stand for some time, and incidental camps. The camps are arranged in the same way in peace and war, as a means of training the men; but, of course, in peace the war arrangements need not be adhered to.

In the instructions issued in 1853 by the Quartermaster-General's Department, the following rules were laid down:—

1. That the front of the camp be made to correspond in extent with the front occupied by the troops in line.
2. That the means of passing freely through the encampment with a large front be maintained.
3. That the tents be disposed with a view to the greatest amount of order, cleanness, ventilation, and salubrity.
4. That the camp be as compactly arranged as the above considerations permit.

The general principle of the encampment is a military one, viz., that the line shall correspond to that in which the troops would engage, viz., in order of battle,† a plan which originated with Gustavus Adolphus. A battalion of infantry being in line, it wheels into open column on the reverse flank, and then pitches its tents. If there are ten companies, there are, therefore, ten rows of tents, each about 36 yards long and 7 broad, the distance between them being the length of the column (36 yards). Or instead of being in open column, every second column closes up, and the tents of two companies are pitched close to each other, back to back. This leaves, of course, a very much wider street between every second row of tents, but the two rows of tents are close together.

In front of the line a broad street is left, on which are three guard-tents. The company officers' tents are in rear of their companies, and behind these

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* In some of the last China expeditions waterproof sheets were issued, of which the men made tents as well as cloaks. I was told by a private soldier who carried one of these, that nothing more comfortable was ever issued to the men. His sheet was the last thing a man would part with.

† Rhodes' "Tent Life," p. 218.

are the field officers' tents, the sutlers, horses, kitchens, and the rearguard. The latrines are usually in rear of all. From 15 to 20 yards separate each row of these tents in rear.

A battalion of 850 rank and file, encamped on its own front either in open column or with the alternate companies closed, will, with all the tents in rear, occupy a space of 230 yards by 138, or 32,000 square yards. But if the space actually occupied by the men's tents, and the unoccupied spaces between the lines of men, be alone considered, the space will be $230 \times 36 = 8280 = 9{\cdot}7$ square yards to each man. If, again, the area of the men's tents only be included, it will be $7 \times 10 \times 36$ or $14 \times 5 \times 36 = 2520$ square yards, or 3 square yards to each person.

If space permit, the next battalion is encamped on the same line, a broad street, equal at least to $1\frac{1}{2}$ companies, being left between the battalions.

Cavalry are encamped in the same way, in columns of troops open, or with the alternate troops closed; 4 feet of space is allowed to each horse, which is picketed.

Artillery encamp with the guns in front, the waggons in two lines behind, officers' tents, &c., in rear again, and the horses and men on the flanks, the men being outside. A troop of horse artillery, with 162 men and 155 horses, occupies a space of 140 yards by 70.

On considering these arrangements, it is evident that the compression of the men is considerable. Taking the oblong space covered by the men's tents, and the spaces between them, and disregarding the space behind with the officers' tents, the space per man is only 9·7 square yards.

But the compression is hardly represented sufficiently by this. Taking the occupied space alone, we find each man has only 3 square yards. Either, then, the ventilation must be extremely good, or more space per man should be given. As in war it is not always easy to give space, the importance, even in a military point of view, of thoroughly ventilating the tents is obvious. It is quite certain that the present bell-tent must be entirely altered.

Whenever practicable, it should be urged on the military officers to give more space to the tents than is allowed in the instructions quoted. The Barrack Commissioners say—"Battalion tents should never be arranged in double line; short single lines are best. The tents in line should be separated from each other by a space at the very least equal to a diameter and half of a tent; and the farther the lines can be conveniently placed from each other the better" (p. 169). The general arrangement must obviously be adhered to; but it would be desirable to abandon the plan of closing up the alternate companies, and to give the length of one and a half diameters of a tent between the tent-pegs of every tent. But, as already said, the important point is to improve the ventilation of the tent itself.

Compressed Camps.—Occasionally the tents have been placed much closer together than even on these plans. It is to be presumed that no military officer who regards the comfort or health of his men will ever do so without an imperative military necessity. Yet it has been occasionally done, and tents have been placed almost as closely as they could be, even when ground was available, and no enemy was in front. Under these circumstances, an explanation of the reasons for not crowding the men together will undoubtedly satisfy the officer in command, that he is sacrificing comfort, convenience, and efficiency, to a false notion of order and neatness.

Points to be attended to in the Erection and Conservancy of Tents.

Place the tents as far apart as can be permitted; have a deep trench dug round each tent, and carry it into a good surface-drain running in front of

the tents, with a proper fall. Place the tent on the ground and do not excavate; in a camp of position, the tents can sometimes be raised on a wall constructed of stones, or even earth, if this can be plastered over. Whenever possible, let the floor of the tent be boarded, the boards being loose, and able to be removed. If there are materials, make a framework elevated a few inches from the ground to carry the boards. If boards cannot be obtained, canvas or waterproof sheets should be used; whatever is used, take care that nothing collects below, and move both boards and canvas frequently to see to this, and scrape the earth if it is at all impregnated. If straw is used for bedding, get the men to use it carefully; to place pegs of wood or stones, and make ropes of straw running from peg to peg, so that each man may keep his own place neat. Take care that the straw is kept dry, and never allow the men to use green foliage, or any damp substance. Have the sides of the tent thoroughly raised during the day, and even at night, to leeward. Whenever practicable (twice a-week if it can be done), the tents should be struck, the boards taken up, the surface well cleaned, the worst part of the straw removed and burnt.

(For conservancy of camps, see War.)

SECTION IV.

Sub-Section I.—Hospitals.

General Remarks.

During the last ten years a great number of works (English, French, and German) have been written on the construction of hospitals. This has been especially owing to the celebrated "Notes on Hospitals," published by Miss Nightingale, after the Crimean war—a work the importance of which it is impossible to overrate—and to the very useful pamphlets of Mr Roberton of Manchester. Among military writers, Robert Jackson in this, as in all other points, takes the first rank, and his observations on the construction of hospitals are conceived entirely in the spirit of the best writings of the present day. In the short space which can be given to the subject here, I can merely condense what has been best said on the subject, as applied especially to military hospitals. In the first place, however, a few words are necessary on the general question.

Although the establishment of hospitals is a necessity, and marks the era of an advanced civilisation, it must always be remembered that if the crowding of healthy men has its danger, the bringing together within a confined area many sick persons is far more perilous. The risks of contamination of the air, and of impregnation of the materials of the building with morbid substances, are so greatly increased, that the greatest care is necessary that hospitals shall not become pest-houses, and do more harm than good. We must always remember, indeed, that a number of sick persons are merely brought together in order that medical attendance and nursing may be more easily and perfectly performed. The risks of aggregation are encountered for this reason; otherwise it would be far better that sick persons should be separately treated, and that there should be no chance that the rapidly changing, and in many instances putrefying, substances of one sick body should pass into the bodies of the neighbouring patients. There is, indeed, a continual sacrifice of life from diseases caught in, or aggravated by, hospitals. The many advantages of hospitals more than counterbalance this sacrifice, but it should be the first object to lessen the chance of injury to the utmost. The risk of transference or aggravation of disease is least in the best ventilated

hospitals. A great supply of air, by immediately diluting and rapidly carrying away the morbid substances evolved in such quantities from the bodies and excretions of the sick, reduces the risk to its minimum, and perhaps removes it altogether. But the supply of air must be enormous; we are not in a position to say how much, but I question whether even the large quantity of 4000 cubic feet per head per hour, now assigned by the best observers, will not be found to be far below the proper amount for the acute and febrile diseases.

The causes of the greater contamination of the air of hospitals are these:—

1. More organic effluvia are given off from the bodies and excretions of sick men. These are only removed by the most complete ventilation.

2. The medical and surgical management of the sick necessarily often exposes to the air excretions, dressings, foul poultices, soiled clothes, &c., and the amount or substances thus added to the air is by no means inconsiderable, even with the best management.

3. The walls and floors of hospitals absorb organic matters and retain them obstinately, so that in some cases of repeated attacks of hospital gangrene in a ward it has been found necessary to destroy even the whole wall. Continual drippings on the floor of substances which soak into the boards and through crevices, and collect under the floor, also occur, and thus collections exist of putrefying matters which constantly contaminate the air.

4. The bedding and furniture also absorb organic substances, and are a great cause of insalubrity.

5. Till very recently, even in the best hospitals, the water-closets and urinals were badly arranged, and air passed from these places into the wards.

In addition to the necessary amount to dilute and remove these substances, the freest supply of air is also now known to be a curative means of the highest moment; in the cases of the febrile diseases, both specific and symptomatic, it is indeed the first essential of treatment; sometimes, especially in typhus and smallpox, it even lessens duration, and in many cases it renders convalescence shorter.*

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* The effect of a great supply of air on some diseases is marvellous, and the subject is so important that a few examples may be quoted. The experience of the fevers in the force assembled at Cork in 1795; of the spotted typhus of 1814 at Paris, when it was noticed with astonishment that the cases placed (with great fear of the result) in the abattoir of Montfaucon (one of the highest and most breezy parts of Paris), did infinitely better than the patients in the regular hospitals; and the analogous case of the Irish fever of 1847–48, when cases left in the open air and in the rudest sheds recovered better than those patients who had all the advantages of the fixed establishments, can be parallelled by many other instances. A case full of instruction for the army surgeon was recorded 100 years ago by Brocklesby, physician to the army in 1764.*

"In October 1758, a greater number of sick were landed out of the transports on the Isle of Wight, than all the spare out-houses, barns, and empty cottages which could be procured for money or the sake of humanity at Newport, were cabable of containing. In this distress, some gentlemen of the hospital proposed to erect a temporary shed, with deal boards, upon the open forest, and to have it thatched over with a coat of new straw, thick enough to keep out wind and rain, and capacious enough to hold 120 patients or upwards; for doing which, and the use of the boards, the country workman exacted forty pounds. Although the hovel was finished in a fashion the most slovenly, and apparently inadequate to the end proposed, upon trial it was found that, notwithstanding much extraordinary cold, as well as moisture, which the sick there lodged had suffered, remarkably fewer died of the same diseases, though treated with the same medicines and the same general regimen, than died anywhere else; and all the convalescents recovered much sooner than they did in any of the warmer and closer huts and barns hired round Newport, where fires, and apparently better accommodations of every sort, could be provided for them." (Pp. 66, 67.)

He gives another instance afterwards.

In making these rough sheds with wattle, Brocklesby incidentally mentions two points of importance:—1. The removing from time to time the ground from the surface, as it gets impregnated with all sorts of things. 2. The building of a large entrance porch, sheltered over head (but not at the sides?), into which the convalescent men can creep, to get as much as possible into the open air, and also to eat their meals in it.

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* Economical and Medical Observations from the year 1758 to 1763, by R. Brocklesby, 1764.

There can, I believe, be no doubt, that the necessity for an unlimited supply of air is the cardinal consideration of the erection of hospitals, and, in fact, must govern the construction of the buildings. For many diseases, especially the acute, the merest hovels with plenty of air are better than the most costly hospitals without it. What ill-judged humanity it is to overcrowd febrile patients into a building, merely because it is called an hospital, when the very fact of the overcrowding lessens or even destroys its usefulness. In times of war, it should never be forgotten by medical officers that the rudest shed, the slightest covering, which will protect from the weather, is better than the easy plan so often suggested and acted on, of putting the beds a little closer together.

The recognition that the ample supply of pure air is the first essential of a good hospital, led Miss Nightingale to advocate with so much energy and success the view which may be embodied in the two following rules :—

1. The sick should be distributed over as large an area as possible, and each sick man should be as far removed as possible from his neighbour.

2. The sick should be placed in small detached and perfectly ventilated buildings, so that there is no great number of persons in one building, and there shall be no possibility of the polluted air of one ward passing into another.

How is this perfect Purity of Air to be secured?

This is a matter partly of construction, partly of superintendence.

(*a*.) There should be detached buildings, so disposed as to get the freest air and the greatest light. They should be at considerable distances apart, so that 1000 sick should be spread like a village ; and in the wards, each man ought to have not less than 100, if possible 120, feet of superficial, and from 1500 to 2000 feet of cubic space.* With detached buildings, the size of an

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Another old army surgeon † records an analogous case. Donald Monro says, that Dr Hume told him, that in 1755, some of the men-of-war carried out to North America a malignant jail fever, brought by impressed men. The fever continued to spread while at sea ; but at Halifax, the sick "were lodged in tents, or in very old shattered houses that admitted the air very freely, which put a *sudden* and effectual stop to this disorder."

The same facts were before clearly pointed out by Pringle, who witnessed the loss occurring in military hospitals when spotted typhus once gained a footing ; and they were also fully understood by Sir James M'Grigor in the Peninsular war. As far as spotted typhus is concerned, no evidence is necessary to convince us that patients must be treated with an absolutely unlimited supply of air ; and with respect to some other diseases, the remarkable experience of the Austrian army surgeons for the last ten years shows that the same rule applies to typhoid fever, smallpox, pyæmia, hospital gangrene, and wounds. Since 1854, the sick of the Austrian army have been largely treated, during eight or nine months every year, in well ventilated tents in preference to fixed hospitals. The result has been most remarkable ; disease was prevented from spreading, and patients got well much more rapidly than in the apparently more comfortable permanent hospitals. For particulars, the Report on Hygiene by the author, in the Army Medical Report for 1862, can be referred to ; some of the most important facts are given under the head of Field Hospitals in War.

An analogous experience has led some of our best surgeons (Mr Paget, for example) to believe that in pyæmia a patient should be treated almost in the open air.

In yellow fever the same rule holds good ; and to show how early this was appreciated, I subjoin a quotation from Lind.

Lind ‡ quotes from "a very sensible man, who resided long in Jamaica."

"I have often observed the poor seamen in the merchant service to recover from the yellow fever solely by having the benefit of a free and constant admission of the cool sea air into a ship anchored at a distance from the shore, where they lay utterly destitute of every assistance in sickness, and even of common necessaries, having nothing but cold water to drink, and not so much as a bed to lie upon ; while gentlemen newly arrived from England, by being shut up in small, close, suffocating chambers at Kingston or Port-Royal, expired, with their whole mass of blood dissolved, flowing from every pore—the stifling heat of their room having produced a state of universal putrefaction in the body, even before death."

* See page 123 for the discussion on this point.

† Donald Monro, vol. i. p. 269.

‡ On Diseases of Europeans in Hot Climates, p. 215.

hospital, as pointed out by Miss Nightingale, is dependent merely on the facility of administration. When the hospitals consist of a single building, the smallest hospitals are the best.

(*b.*) The ventilation should be natural, *i.e.*, dependent on the movement of the outer air, and on inequalities of weight of the external and internal air. The reason of this is, that a much more efficient ventilation can be obtained at a cheaper cost than by any artificial means. Also, by means of open doors and windows, we can obtain at any moment any amount of ventilation in a special ward, whereas local alterations of this kind are not possible in any artificial system. The amount of air, also, which any artificial system can cheaply give, is comparatively limited. The amount of air should be limited only by the necessity of not allowing its movement to be too perceptible.

The best arrangements for natural ventilation for hospitals appear to me to be these—1*st*, Opposite windows reaching nearly to the ceiling, on the sides of a ward (not wider than 24 feet, and containing only two rows of beds), and a large end window. 2*d*, Additional openings, to secure, as far as possible, a vertical movement of the air from below upwards; and this, I believe, will be best accomplished as follows:—*

A tube opening at once to the external air should run transversely along the floor of the ward to each bed, and should end in a box placed under the bed, and provided with openings at the top and sides, which can be more or less closed. In the box, coils of hot-water pipes should be introduced to warm the air when necessary. The area of the tube should not be less than 72 square inches to each bed; and the area of the openings in the box at least four times larger. The fresh air, warmed to any degree, and moistened, if necessary, by placing wet cloths in the box, or medicated by placing chlorine, iodine, or other substances, will then pass under each bed, and ventilate that space so often left unaired; and then, ascending round the sides of the bed, will at once dilute and carry up the products of respiration and transpiration to the ceiling. It would, I presume, be a simple matter so to arrange the hot-water pipes as to be able to cut off all or some of the pipes under a particular bed from the hot-water current if desired, and so to give a fever patient air of any temperature, from cold to hot, desired by the physician. In the low and exhausted stages of fever warm air is often desirable. By this simple plan, it seems to me we could deal more effectually with the atmosphere round our patients, as to warmth, dryness, humidity, and medication, than by any other. At the same time, the open fire-place and chimney, and the open doors and windows, might be preserved.

For the exit of the foul air, channels in the ridge should be provided, warmed by gas if possible, as pointed out in the chapter on VENTILATION.

To facilitate this system of ventilation, it is desirable to have the buildings one storied only; but it can be applied with two stories. Only then the discharge tubes must be placed at the sides, and must run up in the thickness of the walls.

(*c.*) The strictest rules should be laid down with regard to the immediate removal from the wards of all excreta, dirty dressings, foul linen, &c.

Nothing that can possibly give off anything to the air should be allowed to remain a single moment. Dressings of foul wounds should be sprinkled with deodorants, and charcoal bags suspended round the bed.

(*d.*) The walls should be of impermeable material Cements of different

* A plan similar to this has been devised by Dr S. Hale, and adopted in some of the Australian hospitals. It is an excellent arrangement, but seems rather unnecessarily complicated by taking the air under the floor, and elevating the beds on a dais.

kinds are now used, especially Parian; but it may be suggested whether large slabs of properly coloured tiles, joined by a good cement, would not be better. Ceilings should be either cemented or frequently limewashed. Great care should be taken with the floors. On the whole, good oak laid on concrete seems the best material; but the joining should be perfect, so that no fluid may pass through and collect below the floor. Possibly it might be well to cover the floor with a good oil-cloth, or material of the like kind, which would prevent substances from sinking into the boards, and would lessen the necessity of washing the floors, but might be itself removed, and frequently washed. The practice of waxing and dry-rubbing the floors, and other similar plans, is intended to answer the same purpose.

(*e.*) The furniture in a ward should be reduced to the minimum; and, as far as possible, everything should be of iron. The bedding should also be reduced in size, as much as it can be. Thick mattresses should be discarded, and thin mattresses, made easy and comfortable by being placed on springs, employed. The material for mattresses should be horse-hair (18 ℔ weight to each mattress), or coir fibre, which, on the whole, are least absorbent. Straw, which absorbs very little, is bulky, and is said to be cold. All flock and woollen mattresses should be discarded. Blankets and coverlets should be white or yellowish in colour, and should be frequently thoroughly aired, fumigated, and washed.

(*f.*) The arrangement of the water-closets and urinals is a matter of the greatest moment. Every ward should have a urinal, so that the common practice of retaining urine in the utensils may be discontinued. If the urine is kept for medical inspection, it should be in closed vessels. The removal of excreta must be by water. In hospitals, nothing else can be depended upon, as regards certainty and rapidity. The best arrangement for closets is not the handle and plug, which very feeble patients will not lift; but a self-acting water supply connected with the door, and flowing when it is opened. This plan is better than the self-acting spring seat, which is not always easily depressed by a thin patient; and also, by leaving the door open, it gives us the means of pouring in any quantity of water, and of thoroughly flushing the pan and pipe. The closets are best arranged in nearly detached lobbies, at one end of the ward, and separated from it by a thorough cross ventilation, as shown in the plan afterwards given, which is copied from Miss Nightingale's work.

In this way, provided the site of the hospital is originally well chosen, perfect purity of air can be obtained, and the first requisite of a good hospital is secured.

The warming of the air of Hospitals is discussed in the chapter on WARMING.

Next to the supply of pure air, and to the measures for preventing contamination (which embrace construction, ventilation, cleanliness, and latrine arrangements), come the arrangements for medical treatment.

Medical treatment includes—

1. *The Supply of Food.*—The diet of the sick is now becoming a matter of scientific precision; and it is probable that every year greater and greater importance will be attached to it. Hence the necessity of a perfect central kitchen, and of means for the rapid supply of food at all times. There is more difficulty in doing this than at first appears, as the central kitchen cannot supply everything; and yet there must be no cooking in the wards, or even near them, as the time of the attendants should be occupied in other ways. Probably, the best arrangement is to have hot closets close to the wards, where the food sent from the kitchen can be kept warm, and ready for use at all hours of the day and night.

2. *The Supply of Water.*—Hot and cold water must be supplied everywhere, and baths of all kinds should be available. The supply of water for all purposes should be 40 to 50 gallons per head daily.

3. *The Supply of Drugs and Apparatus.*—The chief point is to economise the time of attendants, and to enable drugs and apparatus to be procured without delay when needed.

4. *The Nursing and Attendance, including the Supply of Clean Linen, &c.*—The time and labour of the attendants should be expended, as far as possible, in nursing, and not in other duties. Every contrivance to save labour and cleaning should therefore be employed. Lifts, shafts, tramways, and speaking tubes to economise time; wards arranged so as to allow the attendants a view of every patient; wards not too large nor too small, for Miss Nightingale has conclusively shown that wards of from 20 to 32 beds are best suited for economy of service.

5. *Means of Open-Air Exercise for Patients.*—This ought properly to be considered as medical treatment. As soon as a patient can get out of his ward into the open air he should do so; therefore, open verandahs on the sunny sides of the wards, and sheltered gardens, are most important. For the same reason hospitals of one story are best,* as the patients easily get out; if of two stories the stairs should be shallow.

6. In addition to all these, the supply of air medicated with gases, or fine powders, or various amounts of watery vapour, is a mode of treatment which is sure to become more common in certain diseases, and special wards will have to be provided for these remedies.

The parts of a military hospital are—

Patients' Rooms, Wards, and *Day-rooms,* if possible; the wards of two sizes; large, *i.e.*, from 20 to 32 beds; and small, for one or two patients. It is desirable to have the small wards not close to the large ones, but at some little distance. Attached to the wards are attendants' rooms, scullery, bath and ablution rooms, small store-room, urinal, closets (one seat to every eight men).

Operating-room—Dead-house—Administration.—Surgeons' rooms; case-book and instrument room; offices and officers' rooms.

Pharmacy.—Dispensary; store-room; dispenser's room.

Culinary.—Store-room; wine and beer room; larder and meat room; kitchen; room for arranging diets; scullery; cook's room.

Washing.—Wash-house; dirty linen store; fumigating-room; cleaning-room for mattresses.

Steward's Department.—Offices; furniture, linen, utensil, and pack stores; rooms for cleaning.

The amount of storage room is, for an hospital of 100 sick—

Bedding and store	= 200 square feet.	Fuel store	= 250 square feet.
Clothing store	= 100 ,,	Foul linen store	= 120 ,,
Utensil store	= 160–200 ,,	Pack store	= 200 ,,
Provision store	= 100 ,,	(In military hospitals.)	

* I had never properly estimated the importance of patients getting into the air, and the desirability of one-storied buildings for this purpose, till I served at Renkioi in Turkey during the Crimean war. The hospital was composed of one-storied wooden houses connected by an open corridor. As soon as a man could crawl he always got into the corridor or between the houses, and the good effects were manifest. Some of the medical officers had their patients' beds carried out into the corridor when the men could not walk. In the winter greatcoats were provided for the men to put on, and they were then encouraged to go into the corridor.

SUB-SECTION II.—MILITARY HOSPITALS.

Regulations.

Hospital space is to be provided for 10 per cent. of the force. Lately, since the health of the army has been so much improved on home service, it has been proposed to reduce it to 7 per cent., but it would appear desirable always to have a large hospital space for emergencies and for war.

The Director-General is consulted when a fresh hospital is built.

The Inspectors and Deputy-Inspectors of Hospitals are ordered to inspect the drainage, ventilation, water supply, water-closets, latrines, urinals, and sinks of every hospital, and to see that the warming and lighting are sufficient, also that the number in hospital is not over regulation; that the excreta of the sick are promptly removed from the wards; that cleanliness, cooking, &c., are properly attended to; and that the vicinity of the hospital is in good condition, and the hospital itself in good repair.

In general hospitals a sanitary officer is to be appointed; in regimental hospitals the surgeon or assistant-surgeon is the sanitary officer, and the duties of these officers as to inspection is explicitly laid down.

If any building is selected as a temporary hospital, the sanitary officer, or medical officer in charge, is ordered to inspect it, and to recommend such alterations as are necessary.

Convalescent wards are to be provided when practicable.

In various other places hospitals are referred to in the same sense as in the above extracts.

Military hospitals are either regimental or general. In the former case the medical officer is in charge of the sick of his own corps; in the latter, the sick of many regiments are received, and are treated by medical officers who are usually on the staff, or not doing duty with regiments.

The great improvements in military hospitals which have been made of late years are entirely owing to Miss Nightingale and the Barrack Commissioners (Dr Sutherland and Captain Galton). The old hospitals are gradually being altered as far as they can be, and all new hospitals are constructed on a certain plan.

Condensed into the shortest space, the present rules of construction of military hospitals are as follows:—

The hospitals are to be formed by detached buildings, or pavilions arranged in line or side by side, and, in the last case, to be separated by spaces equal in width to double the height of the pavilion. The pavilions to be so disposed as to get most air and light; to be connected by a corridor with thorough cross and roof ventilation. No sunk basement to be under the wards except to isolate them from the soil, and such basement to be arched, drained, and ventilated.*

Each pavilion for the sick to have only two floors, on account of ease of ventilation, economy of service, and facility for sick men getting into the open air. If possible, one floor is better. Inside staircases, if used, to be large and ventilated separately and thoroughly.

Each floor to have one ward, to hold from 20 to 32 patients,† the wards to

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* See "Notes on Hospitals," 3d edition, 1863, p. 56, *et seq.*; and "Barrack Improvement Report," p. 175, *et seq.*; the text is a condensation of these two.

† Miss Nightingale has shown that these are the limits of size for the common wards, on account of ease of superintendence and attendance, economy of labour, ventilation, and comfort. Each pavilion, if two storied, will then hold from 40 to 64 patients.

contain nothing but the sick and the necessary ward offices. In addition, small wards (one or two patients) for special cases, to be provided off the staircase, or, what is better, located at a distance.

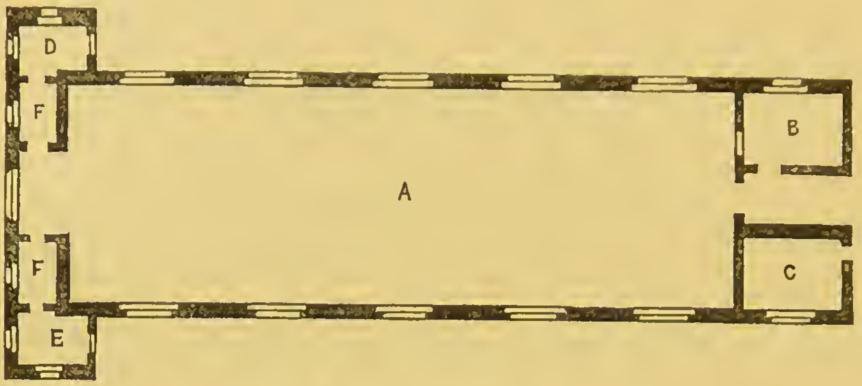

Fig. 80. —Ward for 20 Ward-beds.

A. Ward.
B. Nurse's room, with Ward-window.
C. Scullery.
D. Water-closet and Ward-sink.
E. Bath-room and Ablution-room.
F. Ventilated lobbies.

Each bed to have from 87 to 110 feet of superficial space (viz., for strict regulation, 12 feet in the width of a ward of 24 feet, and 7·25 feet in its length = 87 square feet), and 1200 of cubic space. A ward to have only two rows of beds—20 patients—should be $72\frac{1}{2}$ feet long, 24 wide, and 14 high.

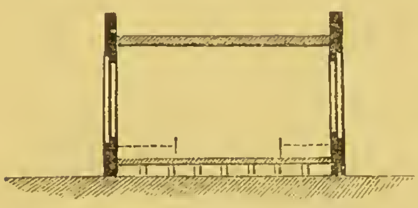

Fig. 81.
Section of Ward to show the Bed.

One window for every two beds, each window to be about 10 feet high, to be double, or of plate-glass, to open near the ceiling. The walls to be of impermeable material, so as to be non-absorbent and easily washed. The floor to be of dense wood (oak preferred), the joints to be perfectly closed with impermeable cement; not to be scoured; to be kept clean by waxing and

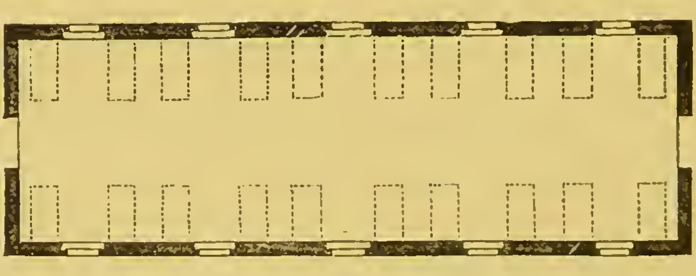

Fig. 82.—Drawing to show Beds and Windows.

rubbing. A nurse's room and scullery opposite, to be at one end of the ward; the apparatus for washing, and as far as right for ward cooking, to be in the scullery. At the other end of the ward two projecting chambers, and between them a large end window. One chamber to contain bath-room and lavatory table; one basin to 6 men, or four for 20. The other chamber to contain one closet for every 10 men (or under), and a sink. It would be well to add an urinal, for which there is room in one corner, as shown in Miss

Nightingale's plan. The closet pans are usually of the syphon form, and of earthenware.

The ventilation to be by windows, doors, open fire-places; inlets placed above the men's heads, and outlet-shafts at the side properly arranged with respect to inlets. (For construction and size see VENTILATION and BARRACKS.)

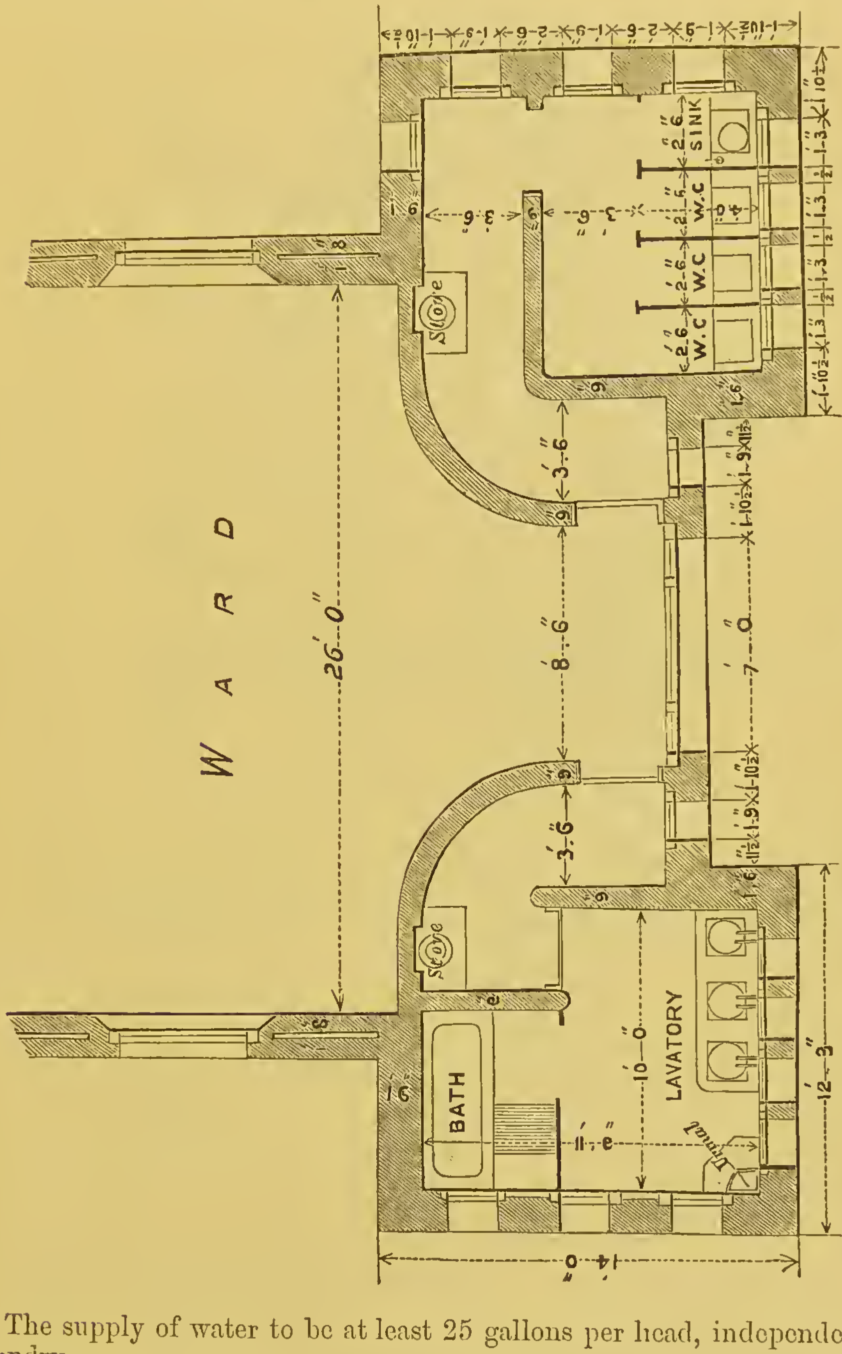

Fig. 83.—Detail of present Ward, Lavatory, Closets, and Urinal, as used in Military Hospitals (from Miss Nightingale's book).

The supply of water to be at least 25 gallons per head, independent of the laundry.

The warming to be by radiation in great measure, in part by warm air proceeding from an air-chamber (see WARMING).

No drain to pass under a building; all pipes from sinks, lavatories, &c., to be in the outer and not the inner walls; all the drains to be ventilated. At the Herbert Hospital "the ward drainage is discharged into vertical

drain-pipes in the outer walls, which drain-pipes are carried from a trap in the main drain below, straight up above the roof of the building, where they are left open to the air. A box of charcoal is placed over the upper opening."*

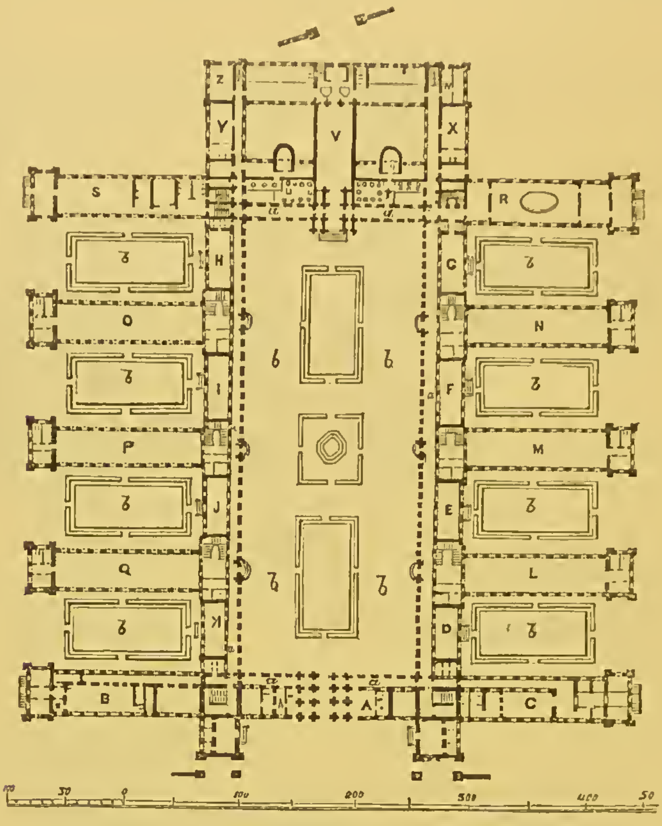

Fig. 84.—Lariboisière Hospital at Paris.

The kitchen to be placed away from the wards, its walls and ceilings to be cemented. The cooking must be of two kinds—ordinary diets and extras.

The foul linen to be at once removed from the wards, and in large hospitals this is best done by a shaft opening above, not into the ward, but into the staircase, or a well-ventilated passage, and below into a small closet, from which the linen should be frequently removed to the dirty linen store. The laundry must be detached, never under the hospital.

The general principle of construction is seen in the three cuts (taken from Miss Nightingale's work), showing the Lariboisière Hospital at Paris, which circumstances have made the type of this system, and the military hospitals at Woolwich and Malta.†

The Herbert Hospital at Woolwich consists of four double and three single pavilions of two floors each, all raised on basements. There is a convalescents' day-room in the centre pavilion. The administration is in a separate block in front. The axis of the wards is a little to the east of north. There is a corridor in the basement, through which the food, medicines, coals, &c., are conveyed, and then, by a series of lifts, elevated to the wards. The terraces on the corridor afford easy means of open-air exercise for the patients in the

* Notes on Hospitals, p. 84.

† In Miss Nightingale's work, and in an article by Dr Aitken (*Brit. and For. Med. Chir. Review*, 1860), will be found plans of small and large hospitals on the pavilion system.

upper ward. The wards are warmed by two central open fire-places, with descending flues, round which are air passages, so that the entering air is warmed. The floors are iron beams, filled in with concrete, and covered with oak boarding.

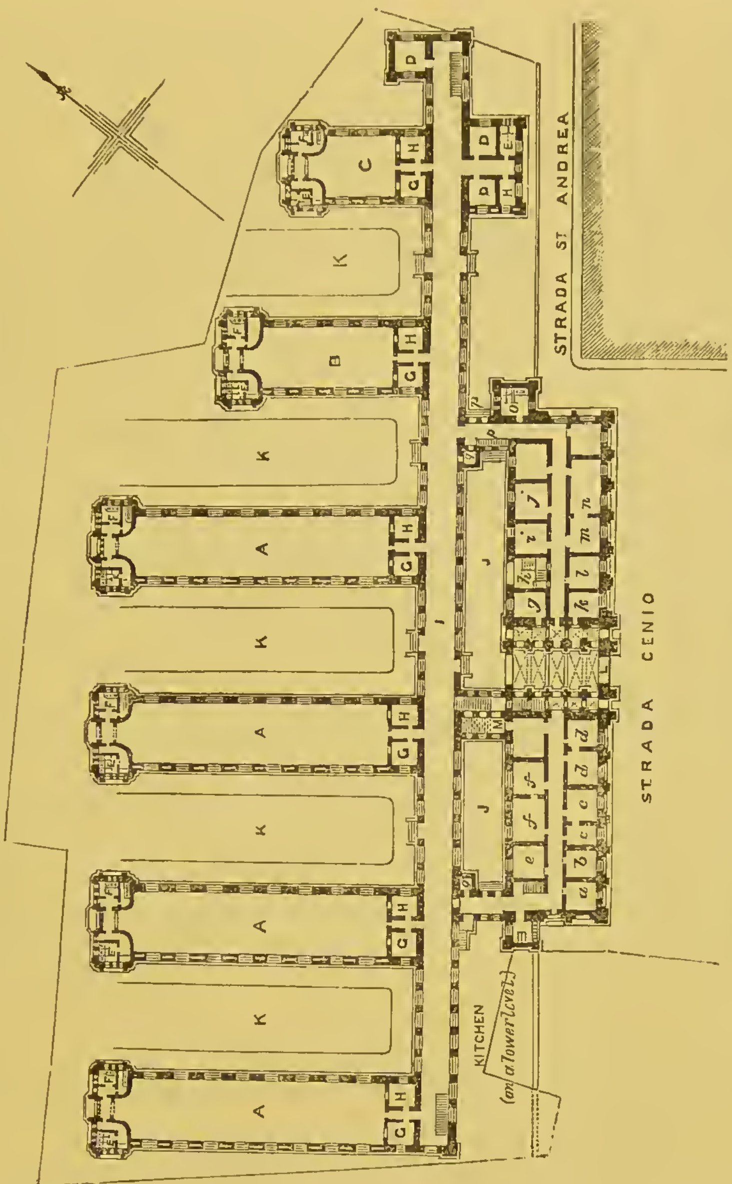

Fig. 85.—Valetta Hospital (from Miss Nightingale's book).

A B C D.—Wards. | G H.—Nurses' rooms and sculleries. | J.—Courts.
E F.—Closets—lavatories. | I.—Corridor. | M.—Staircase.
a to g,—Offices.

Hospitals in the Tropics.

The Barrack and Hospital Commission, in carrying out the plans of the Royal Indian Sanitary Commission, suggest * for each sick man—

Superficial area = 100 square feet, up to 120 in unhealthy districts.
Cubical space = 1500 feet, or, in unhealthy districts, 2000 feet.

It is also directed that hospitals should consist of two divisions—1st, for sick; and, 2d, for convalescents—this latter division to hold 25 per cent. of the total hospital inmates.

* *Op. cit.* p. 27.

Each hospital is to be built in blocks, to consist of two floors, the sick and convalescents to sleep on the upper floors only; each block to hold only 20 to 24 beds.

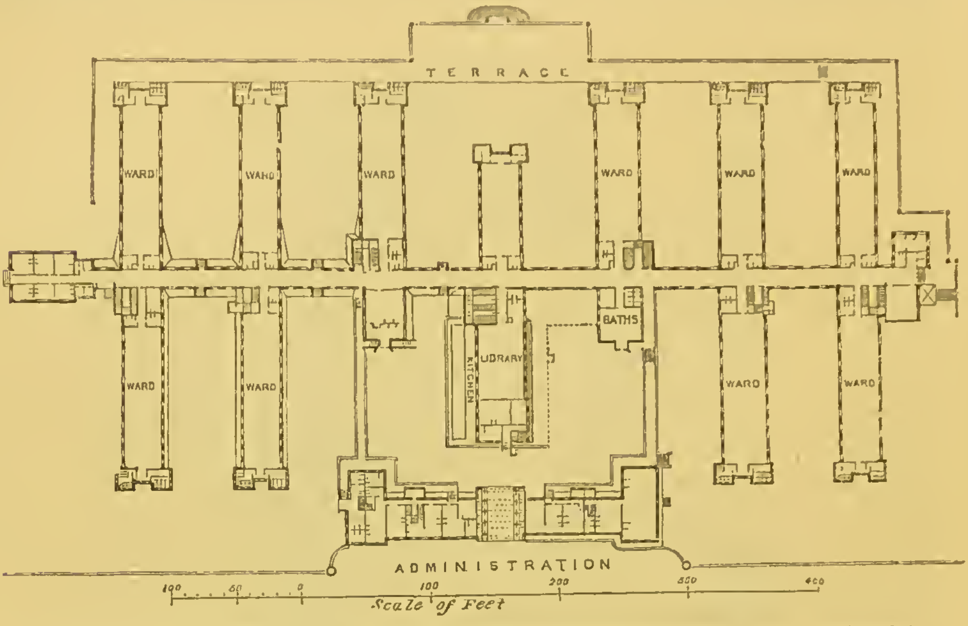

Fig. 86.—Ground Plan of the Herbert Hospital, Woolwich (from Miss Nightingale's book).

The principles and details are, in fact, identical with those already ordered for the home stations.

CHAPTER X.

REMOVAL OF SEWAGE.

We have seen that a regular supply of pure air—in other words, efficient ventilation—is required to remove the excreta of the lungs and the volatile products of the skin. The solid and fluid excreta from the bowels and the kidneys ought to be as rapidly and as completely removed as the gaseous impurities, and the modes of so doing may be conveniently described under the general head of Removal of Sewage.

It is highly probable that to barbarous and inefficient modes of removing the excreta of men and of animals we must partly trace the great prevalence of disease in the middle ages, and there is no doubt that many of the diseases now prevailing in our large towns are owing to the same cause.

When men live in thinly-populated countries, following, as they will then do, an agricultural or nomade life, they will not experience the consequences of insufficient removal of excreta. The sewage matter returns at once to that great deodoriser, the soil, and fertilising it, becomes a benefit to man, and not a danger. It is only when men collect in communities that the disposal of excreta becomes a matter literally of life and death, and before it can be settled the utmost skill and energy of a people may be taxed.

The question of the proper mode of disposal of sewage has been somewhat perplexed by not keeping apart two separate considerations. The object of the physician is to remove as rapidly as possible all excreta from dwellings, so that the air shall not be made impure. The agriculturist wishes to obtain from the sewage its fertilising powers. It is not easy to satisfy both parties, but it will probably be conceded that safety is the first thing to be sought, and that profit must come afterwards.

SECTION I.

AMOUNT AND PRODUCTS OF THE SOLID AND FLUID EXCRETA.

Amount of the Solid and Fluid Excreta.

The amount of the bowel and kidney excreta vary in different persons and with different modes of life. On an average, in Europe, the daily solid excreta are about 4 ounces by weight, and the daily fluid excreta 50 ounces by measure for each male adult. Women and children pass rather less. Vegetable pass more solid excreta than animal feeders, but this is chiefly owing to a large proportion of water.* Taking all ages and both sexes into consideration, we may estimate the daily amount per head of population in Europe at $2\frac{1}{2}$ ounces of fæcal, and 40 ounces of urinary discharge. A population of 1000 persons would thus pass daily 156 lb of solids and 250 gallons

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* Mr Faweus' experiments on Bengalee prisoners give an average bowel excretion of 12 ounces, and in Bombay Dr Hewlett found the alvine discharges to be quite as large.

of urine, or in a year 25 tons of solid fæces and 91,250 gallons (14,646 cubic feet) of urine.

Decomposition of Sewage Matter.

Fresh healthy fæces from persons on mixed diet, unmixed with urine, has an acid reaction, and this it retains for a considerable time; it then becomes alkaline from ammonia. If free from urine, it usually decomposes slowly, and in hot weather often dries on the surface, and subsequently changes but little for some time. The urine, when unmixed with fæcal matter, also retains its natural acidity for a variable number of days, sometimes three or four; sometimes eight or ten, or even longer, and then becomes alkaline from ureal decomposition. When the fæces and urine are mixed, the formation of ammonium carbonate from ureal decomposition is much more rapid; the solid excreta seem to have the same sort of action as the bladder mucus, and the mixed excreta become alkaline in twenty-four hours, while the separate excreta are still acid. And in its turn the presence of the urine seems to aid the decomposition of the solid matter, or this may be perhaps from the effect of the fluid, as pure water seems to act almost as rapidly as urine in this respect. Pappenheim* states that the absorption of oxygen by the fæces is greatly increased when urine is added. When the solid excreta and urine are left for two or three weeks, the mixture becomes usually extremely viscid, and this occurs, though to a less extent, when an equal quantity of pure water takes the place of urine.

When the solid excreta (unmixed with urine) begin to decompose, they give out very fœtid substances, which are no doubt organic; sulphuretted hydrogen is seldom detected, at any rate by the common plan of suspending paper soaked in lead solution above the decomposing mass. When heated, a large quantity of gas is disengaged, which is inflammable, and consists in great measure of carburetted hydrogen. When (instead of being dry) urine is present, ammonia and fœtid organic matters are disengaged in large quantity. When water is also present, and if the temperature of the air is not too low, not only organic matters but gases are given out, consisting of light carburetted hydrogen, nitrogen, and carbonic acid. Sulphuretted hydrogen can be also disengaged by heat, and is almost always found in the liquid, usually in combination with ammonia, from which it is sometimes liberated and then passes into the air.

Air of Cesspools.—The air of cesspools, and especially of the cemented pits which are still common in many continental towns, and which receive little beyond the solid and liquid excreta and some of the house-water, is generally highly impure. Lévy † refers to an extreme case, in which the oxygen was lessened to 2 per cent; the nitrogen being 94 and the carbonic acid 4. In this case, apparently, no other gases were present, but in most instances there is a variable amount of sulphuretted hydrogen,‡ ammonium sulphide, nitrogen, carbonic acid, and carburetted hydrogen, in addition to fœtid organic matters. These organic matters are in large amount. 62 feet of the air of a cesspool destroyed, in Angus Smith's experiments, as much potassium permanganate as 176,000 cubic feet of pure air, though perhaps some sulphuretted hydrogen may have been also present. Oesterlen § states that these gases will pass easily through walls; and M. Hennezel|| has lately noticed that in the "fosses d'aisances" in Paris, even in those covered with stone slabs and earth, the wind blowing down the ventilating tube will force the gas through the neighbouring walls, and then perhaps into the house.

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* Handb. der San. Pol., 2d edit. band i. p. 72.
† Traité d'Hygiène, 3d edit. p. 636.
‡ Barker, On Malaria and Miasmata, p. 245.
§ Oesterlen, Hygiène, 1857, p. 445.
|| Ann. d'Hygiène, Oct. 1868, p. 178.

Products of Sewer-water Decomposition.

In the sewers the products of decomposition may be expected to be more variable, as not only solid and liquid excreta and house water, but the washings and debris of the streets, the refuse of trades, &c., pass into the sewers. As a rule, the products of decomposition of the sewer-water appear to be much the same as noted above—viz., fœtid organic matters, carbo-ammoniacal substances condensing with the water of the air on the cold walls, carbonic acid, nitrogen, light carburetted hydrogen, and sulphuretted hydrogen.* The proportions of these gases are variable;† the most common are carbonic acid and nitrogen; marsh gas is found when oxidation is impeded, and sulphuretted hydrogen and ammonium sulphide, which form in the sewer-water in most cases, are liberated from time to time. The gases, however, are, as a rule, of far less importance than the fœtid organic matters, the exact nature of which it would be most desirable to examine more thoroughly.

The organic vapour is carbo-ammoniacal; the putrid substance in the sewer water appears, from Odling's observations, to be allied to the compound ammonias; it contains more carbon than methylamine ($NH_2(CH_3)$), and less than ethylamine ($NH_2(C_2H_5)$).

The Air of Sewers.—The organic matters and gases proceeding from the dilute sewage-water pass into the air of the sewers. The composition of sewer air will, of course, vary infinitely with the amount of gases disengaged and the degree of ventilation in the sewer. The quantity of oxygen is sometimes in normal amount; it may, however, be diminished in very badly constructed sewers. Parent-Duchâtelet gave an analysis of the air of a choked sewer in Paris, which contained only 13·79 per cent. of oxygen,‡ and no less than 2·99 per cent. of sulphuretted hydrogen. Excluding this analysis, the

* Oesterlen, Handb. der Hyg., 2d edition, p. 445.

† Dr Letheby's experiments, as given in his official Report, in his article in the "Encyclopædia Britannica" (Sanitary Science), &c., and in a letter to Dr Adams (given by Dr Adams in his pamphlet, "The Sanitary Aspect of the Sewage Question," 1868, p. 34), are the most complete on this subject. Taking the last statement of his views as representing his opinion, I gather that sewer-water (containing 128·8 grains of organic matter per gallon), excluded from air, gave out during 9 weeks 1·2 cubic inches of gas per hour, consisting per cent. of 73·833 of marsh gas, 15·899 of carbonic acid, 10·187 of nitrogen, and 0·081 of sulphuretted hydrogen. When atmospheric air is admitted, I infer that Dr Letheby thinks the chief gases are carbonic acid and nitrogen, with but mere traces of sulphuretted hydrogen. That marsh gas in large quantities can be, however, formed, is shown by Letheby's observations on the gases evolved in the London sewers in 1866, where carbolic acid was used; the gas was frequently fired by the candles of the sewer men, and was found to contain 88·45 per cent. of marsh gas, the formation of which was favoured, Letheby thinks, by the action of the carbolic acid; and this is probable, since Angus Smith (Disinfectants and Disinfection, p. 25) found the gas given off by the putrid sewage at the bottom of the Medlock, the water over what was free from oxygen, to contain almost the same quantity of marsh gas—viz., 88·81 per cent.; the other gases being carbonic acid, 5·84; and nitrogen, 5·35 per cent. The evolution of marsh gas will therefore, in part at any rate, depend on the amount of exposure, and on the absorption of air by the sewer-water. Letheby's experiments show less sulphuretted hydrogen than might have been anticipated, both from the large amount of sulphides usually present in sewer-water, and the amount of sulphuretted hydrogen proved to exist in the air of many sewers. With regard to the quantity of gases disengaged, I gave, in the last edition of this work, the amount of 1 to 1½ cubic inch of gas disengaged from London sewage per gallon per hour *in the sewers*, as this is my interpretation of Letheby's account of his experiments, as given in the "Encyclopædia Britannica" (art. Sanitary Science); but Dr Adams, of Glasgow, has pointed out that Dr Letheby's experiments represent the gases disengaged in the laboratory—*i.e.*, at a higher temperature. The amount of gas evolution in the sewers themselves has not been, I believe, actually determined, and will no doubt vary according to the quantity of water, the temperature, rapidity of flow in the sewer, &c.

‡ With respect to this analysis, Parent-Duchâtelet states (Hygiène publ. t. i. p. 249, footnote) that the air was taken "dans la partie la plus salubre de l'égout Amelot;" but in another part of the volume (p. 390) he mentions that the sewer had no ventilation, and that the sewage mud was stirred before the air was collected. Dr Adams ("Sanitary Aspect of the Sewage Question," p. 50) has therefore argued, that the amounts ought not to be placed among the analyses of sewer air, but at any rate they show what can occur in what was called a sewer.

greatest impurity in the old Parisian sewers, as determined by Gaultier de Claubry, in 19 analyses* in 1829, was 3·4 per cent. of carbonic acid, and 1·25 per cent. of sulphuretted hydrogen (in different samples of air). The lowest amount of oxygen was 17·4 per cent. Sulphuretted hydrogen was present in 18 out of 19 cases; the mean of the whole 19 cases being ·81 per cent. The mean amount of carbonic acid in 19 cases was 2·3 per cent. In the present London sewers of good construction the air is much less impure. Dr Letheby found only ·532 per cent. of carbonic acid, a good deal of ammonia, and only traces of sulphuretted and carburetted hydrogen. Dr Miller's experiments in 1867† gave a mean of only 0·106 per cent. of carbonic acid in 18 analyses, and ·307 per cent. in 6 other instances, the oxygen being 20·71 per cent. No sulphuretted hydrogen was present.

It is evident that, if we take the carbonic acid and sulphuretted hydrogen as indices, sewer air has no constant composition. It is sometimes almost as pure as the outside air, while at other times it may be highly impure. But these gases are probably the least important ingredients of sewer air; that organic matters are present is evident from the peculiar fœtid smell, and in some cases they are in large amount; 8000 cubic feet of the air of a house into which sewer air had penetrated destroyed more than 20 times as much potassium permanganate as the same quantity of pure air (Angus Smith). Fungi grow rapidly in such air, and meat and milk soon taint when exposed to it. When the sewer air passes through charcoal these substances are absorbed; they may be partly oxidised, as Dr Miller found some nitric acid in the charcoal, but they also collect in the charcoal, and can be recovered (in part at any rate) from it by distillation.‡

We must also suppose, for facts leave us no other explanation, that the unknown agencies which produce typhoid fever may also be present (see page 109), and there can be little doubt that cholera§ may occasionally spread in the same way. The poison of yellow fever (as appears likely from the epidemic in Madrid) may also exist in sewer air. Whether smallpox, scarlet fever, &c., can own a similar channel of distribution is uncertain; that dysentery and diarrhœa may also be caused by exhalations proceeding from a foul sewer we cannot doubt, but the precise agency is here also unknown.

Effect of Sewer Air on Health.—(See page 107.)

SECTION II.

METHODS OF REMOVAL.

While all will agree in the necessity of the immediate removal of excreta from dwellings, the best modes of doing so are by no means settled. It is unfortunate that some warmth of controversy has been introduced into the discussion on this point, and that a feeling almost of partizanship has arisen. The fact is that several methods of removing sewage are applicable in different circumstances, and their amount of relative utility depends entirely on the condition of the particular place.

The different plans may be conveniently divided into—

1. The water method.
2. The dry method.
3. The air method.

* Parent-Duchâtelet's Hyg. publique, t. i. p. 389.
† Abstract in "Chemical News," March 1868.
‡ Miller, "Chemical News," March 1868.
§ A case in which sewers probably played a part in the dissemination of cholera is given in my Report on the Cholera in Southampton in 1866 to the Medical Officer of the Privy Council.

1. *Removal by Water.*

This is the cleanest, the readiest, the quickest, and in many cases the most inexpensive method of removing sewage. The water supplied for domestic purposes, and which has possibly been raised to some height by steam or horse power, gives at once a motive force at the cheapest rate; while, as channels must necessarily be made for the conveyance away of the waste and dirty water, which has been used for domestic purposes, they can be used with a little alteration for sewage also. It would be a waste of economy to allow this water to pass off without applying the force which has been accumulated in it for another purpose.

But if this is obvious, it is no less so that certain conditions of success must be present, without which this plan, so good in principle, may utterly fail. These conditions are, that there shall be a good supply of water, good sewers, and a proper outfall, and means of disposing of the sewage. If these conditions cannot be united, we ought not to disguise the fact that sewers may give rise to no inconsiderable dangers. For what are they? They are underground tubes, connecting houses, and allowing possibly, not merely accumulation of excreta, but a ready transference of gases and organic molecules from house to house, and occasionally also causing, by bursting, contamination of the ground, and poisoning of the water supply. And all these dangers are the greater from being concealed. It is probably correct, as has been lately pointed out, that in old and broken deep-laid sewers the pressure inwards of the water of the surrounding soil is so great as frequently to cause an inflow *into* the sewer, and so prevent the exit of the contents; but in other cases, the damage to the sewer may be too great to be neutralised in this way, and in the instance of superficially laid and choked-up pipes, the pressure outwards of the contents must be considerable. The dangers of sewers are therefore so great that many persons are inclined to think their use an entire mistake, but this is probably going much too far if certain securities can be obtained; what then are these securities?

(*a.*) *A good supply of Water.*—Engineers are by no means agreed on the necessary amount. In the chapter on WATER, I named 25 gallons per head per diem, on the authority of Mr Brunel, as the amount required to keep common sewers clear, and even with this amount there should be some additional quantity for flushing. But in some cases, a good fall and well-laid sewers may require less, and in other cases bad gradients or curves or workmanship may require more. It is a question whether rain-water should be allowed to pass into sewers; it washes the sewers thoroughly sometimes, but it also carries debris and gravel from the roads, which may clog; while in other cases, storm waters may burst the sewers, or force back the sewage. Other considerations have presently to be mentioned.

(*b.*) *Well-constructed Sewers.*—In order that sewers should be considered really good, the following are essential points :—

At the place of connection with the houses they should be most solidly constructed (which is seldom the case), and should be so arranged that if reflux of gas ever takes place, it may not penetrate into the house. They should therefore never commence in the basement, as the up-draught caused by the artificial warmth of the house will at times draw the gas through any traps. They should either open into partly detached buildings, with good ventilation in the connecting passage, which may cut off the gases from the house, or they should open at the top of the house, so that any gases may escape at once into the air above. At the point of connection there should

not only be a trap, but an opening just beyond, with a ventilating valve, to save the trap from the pressure of the sewer gas.

Passing down from the house, the sewers must be made of the best materials, be well laid, and must be thoroughly ventilated.

Construction.—A convenient division is into house drains and street drains. The former are now almost invariably made of well-glazed round earthenware pipes—the latter of good impervious brick, well set in Portland cement, and of the form of an egg, with the small end downwards. The best size for circular house drains is considered to be 4 to 6 inches diameter for closet and sink drains, up to 15 inches diameter for the larger house drains, which should never be smaller than 6 inches. They ought not to be more than two-thirds full. It is generally considered that the size of the street or main drains should be enough to allow a man to creep through, but some engineers consider this unnecessary, and if the rain-water be excluded, it is perhaps not necessary. In Paris the main sewers are made with paths on each side, just above the stream; a tramway runs on one side which carries a machine, which can at once clear the bottom of the sewer; the entrance of each house drain is marked by a porcelain plate bearing a number; the owner of the house pays a small sum (3 francs) annually to have his house drain kept clean.

Fall and Velocity of Current.—For pipe house drains engineers usually give a fall of 1 in 48; for street drains the fall is much less—from 1 in 50 to 1 in 300, or even less. The fall depends on the size. Mr Wicksteed gives the following table to show the amount of fall for different sizes. If it be admitted that a velocity of about 220 feet per minute is the best for house drains, and 180 feet per minute for the larger street drains, the fall required would be, in the first case, from 1 in 65 to 1 in 87, and, in the second case, 1 in 244 or 1 in 784, according to the size of the drain. Occasionally, with a good supply of water, and when well made, sewers have been kept clear with scarcely any fall, but it is hazardous to trust to this.

Sewers.

Diameter.	Velocity in feet per minute.	Gradient required.
4 inches	240	1 in 36
6 ,,	220	1 ,, 65
8 ,,	220	1 ,, 87
9 ,,	220	1 ,, 98
10 ,,	210	1 ,, 119
15 ,,	180	1 ,, 244
18 ,,	180	1 ,, 294
21 ,,	180	1 ,, 343
24 ,,	180	1 ,, 392
30 ,,	180	1 ,, 490
36 ,,	180	1 ,, 588
48 ,,	180	1 ,, 784

Calculation of the Discharge from Sewers.—Several formulæ have been given, of which the following is the most simple; it is also fairly correct.

Ascertain the hydraulic mean depth when the sewage is flowing, and the amount of fall in feet per mile. The hydraulic mean depth is $\frac{1}{4}$th the diameter if the pipe is running full; if the pipe is not full, it is the section area divided by the wetted perimeter. The wetted perimeter is that part of the circle of the pipe wetted by the fluid. The fall in feet per mile is easily

obtained, as the fall in 50 or 100 or 200 feet can be measured, and the fall per mile calculated (5280 feet = 1 mile). Having got these numbers, multiply the hydraulic mean depth by twice the fall in feet per mile, and take out the square root. Multiply this by 55, and the result by the section area.* The number obtained gives the amount in cubic feet per minute.

Laying and Connection of Sewers.—The greatest care is necessary in the construction, so that there shall be no breakage; pipe sewers must rest on a hard, well-formed bed; the fall should be as regular as possible without sudden differences of level; if there is a great difference of level, a manhole must be provided. The manhole is now often provided with a sliding iron cover to prevent passage of sewer air; or by the side of the manhole a ventilating chamber is placed, into which the sewer air passes, after having first passed through horizontal or vertical charcoal trays. At junctions of sewers right angles must be avoided, and curves with a large radius given; the radius of no curve on a main sewer should be less than ten times the cross sectional diameter of the sewer. Traps must be inserted at the junction of house and street drains, and the common syphon is now usually preferred. The best hydraulic lime must be used for mortar.

Ventilation and Purification.—As gases are largely disengaged, and naturally rise to the upper end of the sewer, there is a continual danger of their passing back into the house in spite of traps; there must, therefore, be many openings into the main sewers, and especially just where the house drains join them, so that there may be no pressure on the trap. House drains should be ventilated near the closet by a pipe running up above the house. The best mode of ventilating is by pipes running up into the air; means of aspiration by furnaces and chimneys have been proposed, but the openings into a sewer are too many for this to act efficiently. The street lamps have been used with advantage as pipes. In certain cases the wind blowing through the open outlet has forced back the sewer gases into houses, and this is likely to occur when the sewer opens above a river or the sea, or if the mouth is left open by the ebb of the tide.

Trays of charcoal (as recommended by Stenhouse) have been used with great advantage by Letheby and others to absorb the fœtid gases of sewers, and in every ventilating pipe there should be one or more trays. Mr Rawlinson now regularly employs them in the sewers of every town he drains. The charcoal absorbs, besides the gases and organic matter, a great deal of water (Miller, Chem. News, March 1868), but this does not impair its power. The charcoal must be in fragments, not too thick, and there should be three trays with two inches of charcoal, or one tray with 6 inches of charcoal. The objection to these trays is that the passage of the gas is sometimes stopped, and it finds a readier exit elsewhere. It should be seen that this is not the case.

The causes of choking of sewers are—

1. Bad lines and gradients. The information on this point must be

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* The formula is— $V = 55 \times (\sqrt{D \times 2F}) \times A$.

V = velocity in cubic feet per minute.
D = hydraulic mean depth.
F = fall in feet per mile.
A = section area.

Mr Hawkesley's formula is—

$$V = \cdot 77 \sqrt{\frac{hd}{l + 2\frac{1}{4}d}}$$

V = velocity in yards per second.
l = length of pipe in yards.
h = head in inches.
d = diameter in inches.

The result must be multiplied by the section area to give the cubic amount.

obtained from the engineer. It should be the first point inquired into when a disease connected with sewage prevails.

2. Imperfect form and workmanship, so that an obstruction is given to the flow, from excessive friction; large, wide, flat sewers are very liable to chokage from this cause. Subsidence of the sewers in loose soils, and fracture, so that the contents escape into the surrounding soil. Sewers made of porous brick allow the fluids to percolate; the solids remain and accumulate.

3. Forcing back of sewage at the outlet by tides or by accumulation of water from rains. Winds also force back sewer gases. So that the mouth of sewers should be protected.

4. Defective water supply.

(*c.*) *Proper Means of Disposal of the Sewage.*—This is the third necessary condition of success, and is by far the most difficult to ensure.

The sewage as found in sewers is very largely diluted with water, and is often not more concentrated than the water of bad surface wells. Its manurial value is thus lessened, and to get a remunerative return an immense amount has to be applied to land.*

The composition is fairly represented in the following analyses:—

Composition of Sewage Water.†

	Grains per gallon.			
	1	2	3	4
Organic matter (soluble),	19·40	41·03	12·3	9·20
„ (suspended,	39·10	17	24·37	
Lime,	10·13	14·71	12·52	11·25
Magnesia,	1·42	1·82	1·59	1·35
Soda,	4·01	2·40	2·41	1·89
Potash,	3·66	3·57	3·31	1·09
Chloride of sodium,	26·40	22·61	34·30	5·58
Sulphuric acid,	5·34	5·31	6·40	3·43
Phosphoric acid,	2·63	5·76	2·48	0·64
Carbonic acid,	9·01	8·92	11·76	4·77
Silica, oxide of iron, oxide of zinc,	6·20	13·55	6·46	
Ammonia,	7·48	8·43	7·88	...
	134·78	145·11	125·78	39·20

One ton of London or Rugby sewage contains only from 2 ℔ to 3 ℔ of solid matter (Lawes).

For the disposal of this sewage-water the following plans are in use:—

Storage in Tank with Overflow.—The sewage runs into a cemented tank with an overflow pipe, which sometimes leads into another tank similarly arranged, the solids subside, and are removed from time to time; the liquid is allowed to run away. Instead of letting the liquid run into a ditch or

* The value of the diluted sewage has been variously calculated; this has been usually done by taking the quantities of ammonia, phosphoric acid, and potash (the three valuable constituents of sewage), as given by analysis per ton, and then estimating the value according to the market price of these three substances. It is believed, however, that the value is not more than 2d. or 4d. per ton, all deductions being made. Some years ago it was calculated by Mr Bazalgette that no less than 431,000,000 gallons of water passed daily from the London sewers. This included rain water. This will show the immense dilution of the sewage.

† Way—Second Report of Commission on Sewage of Towns, 1861, p. 69, *et seq.* Many other analyses have been published.

stream, it has been suggested to take it in drain pipes, ½ to 1 foot under ground, and so let it escape in this way into the subsoil, where it will be readily absorbed by the roots of grasses. In a light soil this could no doubt be readily done; and, if the drain-pipes are well laid, a considerable extent of grass land could be supplied by this subterranean irrigation. The tank plan is, however, only adapted for a small scale, such as a single house or small village. If properly arranged, with ventilation between the house and tank, it answers well.

Discharge into Running Water.—The sewage is at once discharged into a brook or river. This has been the usual plan in England, but it is now being disused. The waters of many streams have been made foul in this way; much danger has been produced by contamination of drinking water; injury has been done to the beds of the streams by silting up from the great deposit; injunctions have been obtained at common law against some towns for making a nuisance, and in other cases (as in the upper valley of the Thames,* and in the water-shed of the River Lee) special enactments have been made to prevent the passage of sewage into rivers. In all probability some general Act will soon be passed entirely prohibiting the pollution of streams by sewage.

When sewage thus passes into a river, and is mixed with a large body of water in motion, it soon begins to be oxidised, and in process of time the organic matter is entirely changed into nitrates, nitrites, ammonia, and carbonic acid. The length of time which this conversion requires is not exactly known, and will depend obviously on dilution, temperature, amount of oxygen, agitation, &c. Dr Letheby has stated,† that if sewage is mixed with 20 times its bulk of water, and has a flow of 9 miles, it will be perfectly oxidised. Water plants are also great purifiers.

It is evident, however, that this process of oxidation cannot be depended upon for perfect safety, and some parts of the sewage (such as epithelium cells) may possibly be undestroyed after a longer transit than 9 miles.

The contamination of rivers by the matter poured into them by sewers is not wholly caused by sewage matter. In manufacturing towns all kinds of refuse, chemical and mechanical, is thrown into the sewers. In some cases (as in the instances of towns with iron-works where acids are largely used) these matters may even purify the sewage, but in many instances they must add largely to the contamination of the stream.

Precipitation.—Another plan is not to pour the whole sewage into rivers, but to precipitate the solid part, or the greater portion of it, and then to allow the liquid to pass into the stream.

This is sometimes done by simple subsidence, the sewage being received into settling reservoirs or trenches, with strainers to arrest the flow to some extent. When the solid matter has collected to a certain extent, the sewage is turned into another reservoir, and the thick part being mixed with coal refuse or street sweepings, is sold as manure. At Birmingham this substance sells for about 5s. a ton, and is carted away by the buyer.

Filtering beds are now almost universally given up, as they are so soon clogged.

The thin water which runs off must be almost as dangerous as the sewage itself when poured into streams, and no doubt the prohibition to discharge sewer-water will extend to it also.

In order to produce greater purification, the sewage in the subsiding

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* Thames Navigation Act of 1866.

† East London Water-Bill Committee (1867), p. 430, questions 732-734.

reservoirs is sometimes mixed with chemical substances, which cause the deposit to take place more completely and more rapidly.

At Leicester, lime has been used for this purpose, and the precipitate caused in the sewage has been separated by centrifugal force. The water thus obtained is clear, and has been often drank without any taste being detected. When passed into the river it does no injury to fish. It appears, however, from Dr Frankland's analysis,* that about 40 per cent. of nitrogen of the organic matter still remains in this water. A process patented by Mr Sillar,† the chief ingredients in which are animal charcoal, blood, and alum refuse, has an effect very similar to the lime process.‡ The sewage separates into water and sediment; the water, according to Frankland, contains about 45 per cent. of the organic nitrogen, being in this respect a little inferior to the lime plan; the sediment, however, is richer in ammonia, and as it is acid, instead of alkaline (as in the lime plan), the ammonia is fairly retained, and the manurial value is higher. According to Dr Frankland, neither the lime nor Sillar's plan purify the supernatant water sufficiently to allow it to be discharged into streams.§ It must, however, be conceded that either plan would prevent the silting up of streams, and probably that the nitrogenous matter would soon become oxidised in running water; experiments are, however, wanted on this point.

Aluminous earth, mixed with sulphuric acid, has been used by Dr Bird, and is now employed at Stroud. The effect is somewhat similar to that of the lime. The sediment is said to have a good value as manure. In Germany a mixture of lime, magnesium chloride, and coal-tar has been used by Süvern. A great number of other substances have been used, some of which will be alluded to in a subsequent section; but at present one verdict must be passed on all, viz., that though effectual to a certain point, they do not carry the purification of the water to such a point as may avoid all risk of danger, if it is discharged into streams from which drinking-water is taken.

Application to Land.—At present this is the favourite plan in England, and certainly it has very great advantages. If the system is properly carried out, the sewage is well purified. The result of the experiments by Lawes and Gilbert || may be thus stated—

	In one gallon Water.			
	Before application to Land.		Running off Land.	
	1st Experiment.	2d Experiment.	1st Experiment.	2d Experiment.
Total mineral solids, . .	91·26	98·22	37·52	40·75
Total organic matters, . .	51·6	42·4	7·8	7·05
Ammonia, ...	8·66	8·78	·98	·92

Occasionally more of the ammonia runs off, and some nitrogenous organic matter, but usually it has been oxidised into nitric acid. Phosphoric acid

* Chemical News, Nov. 6, 1868, p. 218.
† The A, B, C Sewage Process. London. Second edition. 1868.
‡ Report on Sillar's Process by Dr Frankland, Chemical News, Nov. 1868.
§ Mr Sillar has stated (*op. cit.*), p. 22, that the process removes 77·48 per cent. of the organic matter.
|| On the Composition, Value, and Utilisation of Town Sewage, by Messrs Lawes and Gilbert. 1866.

and potass are retained by the soil to a considerable extent; soda in the next place, magnesium to a less extent, and lime still less.

At Croydon the land sewage-water contains about 24·68 grains per gallon, of which 2·58 are organic. This is a much higher purifying effect than precipitating agents have yet accomplished; at the same time it is not certain that the land sewage-water would be innocuous; the power of the soil has a limit, and it is evident that care must be taken in the application of this plan, so that it may be really efficient, and not contaminate streams.

The best soil on which to apply the sewage is a good loam or loamy sand; the clay soils, if very impermiable, are not so well adapted. The best crop is grass (especially Italian rye-grass), because the sewage can be applied all the year round, but it may also be applied with advantage to arable land. It appears that 5000 to 6000 tons of this liquid sewage can be given annually per acre, which is equivalent to the excreta of from 80 to 100 persons per acre per diem. At Croydon 250 acres receive the excreta of nearly 20,000 persons, or about 80 persons per acre. The estimate of Lord Essex was 60 acres per 4000 persons, or 66 persons to an acre. Mr Bazalgette * considers that 100 persons to an acre may be taken as the standard. A town of 10,000 persons would thus require 100 acres, and one of 100,000 would require 1000 acres. It will be seen, therefore, that a large town requires a very great quantity of land.

Are there no sanitary evils in such a plan? Of course, there must be some effluvia from the land thus flooded with sewage, but it is certainly remarkable how soon it disappears. Sewage has been applied to land for years without bad effect; but there are a few instances to the contrary, and more evidence is necessary on this point. (See p. 112, case by Dr Clouston.) It is therefore advisable to get as far as possible from dwellings.

In order to prevent decomposition and smell, deodorants are sometimes mixed with the sewage in the sewers, or at the outfall. At Carlisle, Messrs MacDougall use their carbolate and sulphite powder; in other places carbolic acid has been used. A good effect is produced in this way, but a considerable quantity of the deodorant must be used.

It appears to be of importance to apply the sewage in a fresh state.† At Croydon, it is said to be on the land often within six hours after it is passed. The engineering details of the application to land differ in each case; wherever the sewage reaches the land by gravitation, the plan is profitable, and sometimes very much so; when it must be pumped, the cost will depend on the height to which it must be lifted or forced, and on the price of fuel, labour, and machinery. The pumping is a difficulty; but as the cost has been very greatly lessened of late years, it is not quite so serious a matter as it formerly was.

The sewage is sometimes distributed over land as it is received; in other cases, the thin part, after subsidence of the sediment, is used. The sediment is mixed with street refuse and carted away.

Separation of the Rainfall.—One difficulty about the application to land is the enormous quantity of fluid, which is composed not only of the liquid sewage, the house-water supply, but of the town and trade supply, and of the rainfall; the cost of pumping and distribution, and the difficulty of applying it at all times of the year, are much increased.

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* Report of East London Water-Bill Committee, p. 437.

† At the Littlemore Asylum, in Oxfordshire, where the sewage of 570 patients and their attendants (say 50 more) flows over 16 acres (which gives nearly 40 persons to an aere), it has been found for several years that the application of the fresh and highly dilute sewage to land gives no emanation, and there has been no bad effeet on health. The amount of fluid put on the ground, exclusive of rain-fall, is 54 inches per square inch per annum.

It has been proposed to get over this difficulty by the separation of the rainfall from the sewage-water, and this is sometimes called the separate system. The carrying out of Mr Ward's celebrated phrase, "the rain to the river, the sewage to the soil," has been strongly advocated by many eminent inquirers.*

Its advantages are obvious; a much smaller amount of fluid has to be disposed of at the outfall, so that less pumping is necessary; the amount of sewage to be disposed of is more uniform from day to day, smaller sewers can be used, and there is no road debris to be carried into the sewers. On the other hand, the scouring effect of the rain is lost, and a double set of pipes is necessary, one for the sewage, the other for the rain. But these disadvantages are probably more than compensated by the gain in some cases.

In this country local circumstances must decide the point. If proper land be available, and gravitation can distribute the sewer-water, it would be best not to separate the rainfall; but in many low lying towns, where costly pumping is required, or where the available land is small or ill arranged, the "separate system" will be the best.

In India, where the rainfall is excessively heavy, it is almost impossible to use the sewers for this purpose. In Calcutta, where it is to be attempted, the main sewer is as much as 30 feet wide.† At Madras the rain-water is proposed to be taken away in open channels leading into the present surface drains.

Passage into the Sea.—The passage of sewage into the sea, when it can be done, avoids many difficulties. It is, however, essential that the sewers should run out into deep water, and in such a position as that there shall be no reflux on shore. The mouth of the sewer should never be exposed at the lowest tide. The great disadvantage of the discharge into the sea (in addition to the agricultural loss) is the occasional retention of the sewage.

Such, then, appears to be the present position of the question of the removal by water, and I believe that, under the conditions named, the verdict must be favourable to the plan, with in some cases inclusion of the rainfall, and in others by the so-called separate system, when the rainfall has its own channels.

Still there will always be the danger of clogging of sewers, and to avoid this a modification of the water plan has been proposed, which, for convenience, may be termed—

Water Removal, with local Interception of Solids.

In some parts of Paris, Milan, Turin, and other continental towns, the excreta fall into a large receptacle with perforated sides or bottom, or into a double cylinder, the inner cylinder being perforated. The urine and water drain off; the solids are retained, and are removed from time to time, either by common cartage, or by means of an engine which draws out the contents by exhaustion. In some cases these receptacles are of great size, and placed outside the house; in other cases they are in the house, and are then usually ventilated by upright pipes. In Paris, the solids, after removal, are mixed with lime slaked with urine (which would seem by no means a good plan), and are sold for manure. In 1863, this "chaux animalisée" was sold in Paris for 38s. per ton.‡

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* This question is well dealt with by Mr Menzies, and lately very completely yet briefly by Colonel Ewart, R.E., in his report to the Home Office on the drainage of Oxford, Eton, Windsor, and Abington (1868). He advises very justly the separation of the rainfall in these towns.

† On the Drainage of Madras, by Captain H. Tulloch, R.E., 1865, p. 88.

‡ How can our Town Sewage be Best Preserved and Utilised? By J. Edmeston, 1863, p. 3.

An important modification has been introduced into this system by Mr Chesshire of Birmingham. In the continental plan, the solid excreta, with the adherent urine and water, are freely exposed to the air, and much gas is disengaged,* but Mr Chesshire proposes to limit the amount of air. He employs an iron intercepting tank or box, which is hermetically closed, and one corner of which is partitioned off by a galvanised iron-wire grating; the water-closet pipe enters at the top of one end, the discharge pipe runs from the space enclosed by the partition into the sewer. Both the closet and the discharge pipes are trapped by syphons. The result is that the urine and water drain away and leave the solids, in which decomposition goes on with great slowness owing to the restricted access of air, for it is only when the closet is used that a limited amount of air can pass in with the water. The box is placed in the rear of the house, or in the area, or under the curb-stone of the street, or at any place most convenient for the occasional opening and removal of the contents.

It is obvious that this plan does away with one of the advantages of the water method. The carrying power of the water is no longer used for the solids, which must be removed by hand from time to time. Hence, additional labour and surveillance are necessary, and the chances of neglect are increased. So also there is a possibility of the straining partition in the box being blocked by the viscid solid excreta.

On the other hand, it has these great advantages. The sewers can never be clogged, since only urine, water, and some dissolved fæcal matters will pass through; if anything is thrown in from the house it will be stopped in the box. The sewers can, therefore, be made much smaller; in fact, small glazed pipes are quite sufficient, and the amount of discharge at the outfall is so moderate (since the rain is excluded) as to be easily applied to land. And if the value of the solids in the intercepting box be enough to pay for the removal of the contents and the supply of the boxes, it will not much matter if some of the water power is lost.

There is one sanitary point, however, of great importance. Is the disengagement of gas from the solids in the box so slight as really never to lead to pressure of gas through the closet trap? Mr Chesshire informs me that scarcely any gas is generated, and that when opened the contents of the box have little odour. I have seen with him several of these boxes opened, and certainly in these cases the formation of gas was trifling. But I should not like to speak with confidence on this important matter without much more evidence. It may, however, be said that the possible value of the plan is so great that it ought to receive an official trial, as if it fulfils the hopes entertained of it, it might solve many of the sewage difficulties. Of course, the decomposition of the solids can be arrested by antiseptics, but then the regular use of antiseptics as a matter of household routine cannot be relied upon.

Form of Water-Closets.—On this point little need be said; many patents have been taken out, but practically they almost all resolve themselves into some modification of the syphon. A good shaped cone and a simple syphon, with a good flow of water, is the best, and it is easily cleaned if it gets out of order. Mr Jenninngs has patented a syphon with a plug, which would seem to render reflux of gas almost impossible. The flow of water can be connected with a handle, the seat, or the door of the closet. The latter is the most certain plan of ensuring that water in sufficient amount is poured in. In barracks, water latrines are used instead of closets (see Barracks).

* See a paper on the Ventilation of Fosses et Cabinets-d'aisances in Paris, by M. Hennezel. Ann. d'Hygiène, October 1868.

Ventilation of Closets.—Good cross ventilation by windows, and a small pipe rising up inside the wall to the open air, and protected by a small hood, answers as well as any plan. If a gas jet is placed below the pipe, it both lights the closet and creates an upward current.

2. *The Dry Method.*

The use of sewers, and removal by water, is in many cases impracticable. A fall cannot be obtained; or there is insufficient water; or the severity of the climate freezes the water for months in the year, and removal by its means cannot be attempted. Then either the excreta will accumulate about houses, or must be removed in substance daily or periodically. Even when water is abundant, and sewers can be made, many agriculturists are in favour of the dry system, as giving a more valuable fertilising product; and various plans are in use.

In some, the solid and liquid excreta pass into boxes or tanks, which are emptied daily, and the sewage is at once applied to land without further treatment. In Glasgow, the excreta from one part of the town, containing 80,000 people, are now removed every day without admixture, except with the garbage from the houses, and are sent long distances at a profit. This system is profitable; it is carried out in England in some barracks; and Liebig has given an account of the barracks at Baden, where the excreta of about 8000 men are removed daily, and have converted the sandy wastes about Rastadt and Carlsruhe into fertile corn-fields. The annual profit was L.680 in 1858. If this can be done effectually, it is the best plan; it should not be applied in the immediate neighbourhood of dwellings, and the Barrack Commissioners have ordered that it shall not be put on land nearer barracks than 500 yards.

In other cases, the soil being removed daily, or from time to time, is taken to a manufactory, and there subjected to manipulations which convert it into a manure.

Under the term "Poudrette," manufactories of this kind have been long carried on in France, though they are said not to be very profitable. At present, however, a portion of the nitrogen of the urea is converted into ammonia, and is united with sulphuric acid, and comes into the market as sulphate. In England, also, there have been several manufactories, such as the "Hyde Patent Manure Eureka Company," who reduced the soil to one-seventh of its bulk by the application of heat, and obtained a good manure. Actions for nuisance, on account of the effluvia, and the expense of the process, caused, however, the company to wind up.

There have been great discussions as to the salubrity of the French poudrette manufactories, and the evidence is, that they are not injurious to the workmen or to the neighbourhood, although often incommodious. But the poudrette can take on a kind of fermentation which renders it dangerous, and Parent-Duchâtelet has recorded two cases of outbreaks of a fatal fever (typhoid?) on board ships loaded with poudrette. In the case of the Eureka Company no bad effect was produced on the health of the men.

Usually, however, some deodorising substance is mixed with the soil before it is removed from the house, and it is then at once applied to land without further preparation. Mr Moule's advocacy of the use of dried earth has brought into prominent notice the great deodorising powers of this substance. and perhaps no suggestion of late years has had more important consequences.

Earth Closets.—Mr Moule's earth closet consists of a wooden box, with a receptacle below, and a hopper above, from which dried earth falls on the

sewage when the plug is pulled up. The earth is previously dried, and about $1\frac{1}{4}$ to $1\frac{1}{2}$ ℔ of the dried earth per head daily is the usual allowance. For a single house, the earth can be dried over the kitchen fire; but if a village is to be supplied, a small shed, fitted with tiles, below which smoke pipes from a small furnace pass, is required. The earth used in the closet is sufficient to deodorise the solid excreta, and the portion of the urine passed with them; but the rest of the urine and the house-water has to be carried off in pipes, and disposed of in some other way. The receptacle is emptied from time to time, and the soil is stored until it can be applied to land.

The advantages of this plan are obvious; its disadvantages are the necessity of collecting, and drying, and storing the earth, which for cottagers who have little space, and possibly no means of getting earth, is a serious matter. The supply of dried earth to large towns is almost a matter of impossibility, so large is the amount required.* Again the attention necessary to prevent the house-water being thrown in, and to remove the soil at sufficiently short periods, sometimes militate against the success. To obviate these disadvantages, some modifications have been introduced into Moule's closet; one side of the receptacle may be covered with a grating, leading to a pipe, so that all fluids drain away, and the house-water can be thrown in. In another plan the urine is carried away without mixing at all with the solid excreta. Sometimes the urine thus separated is led into another box of earth, and is thus more easily disposed of, if there are no means of taking it entirely away; or it is passed into a tank, and then used as liquid manure. This separation of the urine and solids certainly appears to be an improvement.

In order to avoid the large amount of earth, other deodorants are used; charcoal (which is, however, too expensive); M'Dougall's and Calvert's powders, mixed with sifted ashes; ashes sprinkled with sulphuric acid; or cinders and chalk, &c., have been used. In various towns of England ash-closets are used, in principle the same as the earth closet, but with ashes instead of earth. In Prussia the deodorising powder of Süvern is much used; it is a mixture of lime, magnesium chloride, and coal-tar.

Mr Taylor's Revolving Disk.—Mr Taylor, of Rumsey,† has proposed an entirely new plan, which was, in part, in operation before Mr Moule's closet became popular. In order to do away with the necessity of the dry earth, or at any rate of so large a quantity, he attempts to dry the excreta by separating the urine, and exposing the solids on a revolving disk, which is placed below the seat, and which is moved slightly round by a simple lever whenever the lid of the closet is lifted; by the time the circle is completed the solid part is nearly dry, and is scraped by a knife into a receptacle, from which it is emptied from time to time. A hopper is placed above, from which a little dry earth, or more usually sifted ashes, with $\frac{1}{10}$th part of Calvert's or M'Dougall's powder, can be thrown on the soil. In this plan the urine runs off at once into a neighbouring ditch, or tank, or into earth, or is disposed of in any convenient way.

The disks are 3 feet 6 inches or 5 feet in diameter, according to the number of persons. The house-water can be thrown into this closet.

In hot weather the sewage dries completely, and is quite inodorous; in wet weather it is less dry, but still the odour is trifling. There is very little trouble with this turn-table, and it requires much less earth, but it has some

* For workhouses, prisons, barracks in country places, where there is plenty of labour, and no difficulty in obtaining and afterwards in disposing of the earth, the plan is almost perfect. So also for small villages, if some central authority arranges for the supply of earth, and for the removal of the used soil.

† British Guano, by Francis Taylor, 2d ed. 1864.

disadvantages; it is more complicated and costly than the common earth closets; if any part of the lever breaks the action stops, and this may not be detected for days; the disk gets very much soiled, and requires scraping from time to time; if the closet is used more than has been arranged for, the sewage does not dry. The plan seems well adapted for hot places.

There is one evident objection to all these dry plans, viz., that the excreta are retained about our houses for some time. No doubt, when mixed with earth, they are inodorous, and it is presumed harmless; but of this no evidence has been given. What would be the result of cholera or typhoid discharges received in earth and allowed to remain in the house?

The dry system is coming into great use in India, and is carried out with great attention to detail. In those European stations where water is not procurable, Mr Moule's invention has been a boon of great value, and I have been told by medical officers that nothing has been done in India of late years which has contributed so much to the health and comfort of the men.* The plan of separating the urine from the fæces has been strongly advocated by Dr Cornish of Madras, and would no doubt be attended with great advantages in India, if there are means of disposal of the urine.

In the case of natives of India, however, a serious difficulty arises in the use of the earth system, in consequence of the universal use of water for ablution after using the closet. Every native takes with him a small vessel holding 10 to 20 ounces of water, so that a large amount of fluid has to be disposed of. The usual earth closet does not suffice for this, and the water and urine must be separated. Mr Charles Turner, C.E., of Southampton, has contrived a closet suitable for the native family;† it is unfortunately rather costly, and possibly a simple iron box, with a pipe to carry off the urine and ablution water, would be better suited for the poorer classes.

It appears from the observations of Mr Fawcus, at the jail of Alipore, that more earth must be used for vegetable than for animal feeders; the experiments gave 5·1 ℔ avoir. ($2\frac{1}{2}$ seers) of undried earth for the daily evacuation of a vegetable-feeding Hindoo. The urine discharge (2 ℔) required 8·2 ℔ of earth. The earth was efficacious in proportion to the vegetable organic matter or humus. The earth required to be thoroughly mixed with the excreta. In the experiments in this country the clayey matters (silicates of alumina) seem to be chiefly useful.

Comparison of the Wet and Dry Systems.

As already said, circumstances differ so greatly that no rule is applicable to all cases.‡ Isolated houses, small villages, &c., are particularly adapted

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* An account of the Bengal arrangements will be found in the 2d edition of this work, p. 329. I have now omitted it, as the plans are being much altered.

† This was done at the suggestion of Dr Niven, of Bombay. Mr Turner's closet is described and figured in my Report on Hygiene for 1867, Army Medical Report for 1866, published 1868, vol. viii. p. 307.

‡ Some valuable information and discussion on the whole subject of sewage will be found in the account of the Leamington Congress on the Sewage of Towns (1866), edited by Mr Hitchman. Dr Hawkesley's paper in the volume says perhaps everything that can be said in favour of the earth system. In Germany the subject is attracting much attention. Varrentrapp has lately published a work ("Ueber Entwässerung der Städte," von Dr G. Varrentrapp, Berlin, 1868), in which a good account is given of the plans in many continental and English towns; the water removal is strongly advocated. In Berlin an animated discussion has taken place on the point (Die Kanalisation von Berlin, 1868), in which Virchow (Archiv, für Path. Anat., band xlv. p. 231, "Canalisation oder Abfuhr"—which may be translated Sewerage or Dry Removal) has taken part. Virchow's paper is a very able discussion, and he comes to a conclusion very similar to that given above, viz., that both plans have their advantages; that "Canalisation" is more fitted for large cities, and "Abfuhr" or dry removal for small towns and country places. A number of other works have also been published in Germany.

for the dry plan; in fact, in many instances no other can be used. The value of the manure will also often pay all the expenses.

But in large towns the cost of labour of removing the excreta, and of supplying dried earth (if earth be used), is believed by many engineers to be fatal to the use of the plan. Calculations have been made as to the amount of earth required, and the quantity will be found to be very large, if anything like 1 ℔ daily per head is to be supplied. The first cost of the closet is also increased by the necessity of a drying apparatus; this, however, is not very great, for the drying can be done for districts, and a single furnace, with flues running under a brick floor like a Roman hypocaust, can dry enough earth for many houses. There is, however, a continual cost incurred by the necessity of supplying earth and removing the sewage. It is not yet known by actual trial whether the value of the earth sewage (which would necessarily fall, if much were obtainable) would pay for the expense of cartage and removal.

The advocates of the dry plan believe that these difficulties are exaggerated, and that a trial will dispel all misgivings. It is much to be wished that an official trial, on a scale large enough to fairly test the system as applied to towns, could be made. As already said, for villages where water is scarce, or outfall and disposal of water sewage difficult, the question is more easily settled, and the dry system in one of its forms leaves little to be desired.

3. *The Air Plan.**

A Dutch engineer, Captain Liernur, has proposed an entirely novel plan. No water or earth is used, but the excreta are extracted from iron pipes, into which they fall by exhaustion of the air. The extracting force which can be used is said to be equal to a pressure of 1500 ℔ per square foot, which is sufficient to draw the excreta through the tubes with great rapidity. I am not aware that the plan has yet been tried on a large enough scale to test it fairly; and since it depends on the power of creating a vacuum, and would at once be inoperative if the most trifling thing injured the pipes, it seems unlikely at first sight that this ingenious idea should be mechanically successful.

SECTION III.

ON THE INFLUENCE THE CONSTRUCTION OF SEWERS HAS HAD ON THE DEATH RATE OF TOWNS.

Reference has already been made to the possibility of sewers being the channels by which enteric fevers and cholera have been propagated from house to house, and from which emanations, causing diarrhœa and other complaints, may arise. Admitting the occasional occurrence of such cases, it remains to be seen whether the sanitary advantages of sewers may not greatly counterbalance their defects. The difficulty of proving this point statistically consists in the number of other conditions affecting the health of a town in addition to those of sewerage. Dr Buchanan † has given some valuable evidence on this point, which has been well commented on by Mr Simon. He inquired into the total death rate from all causes, and the death rate from some particular diseases, in twenty-five towns before and after sanitary im-

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* An account of this system is given by Mr Krepp, "The Sewage Question, 1867," and there has been much discussion in some of the engineering journals. I have given some notice of it in the Report on Hygiene in the Army Medical Report for 1867. Mr Krepp is a strong advocate, and his account must be taken with limitation.

† Ninth Report of the Medical Officer to the Privy Council, p. 12 *et seq.*, and p. 40.

provements, which consisted principally of better water supply, sewerage, and town conservancy. The general result is to show that these sanitary improvements have resulted in a lowering of the death rate in nineteen out of twenty-five towns, the average reduction in these nineteen cases being 10·5 per cent. The reduction in typhoid (enteric) fever was extremely marked, and occurred in twenty-one towns out of twenty-four, the average reduction being 45·4 per cent. in the deaths from typhoid. In three cases there was an augmentation of typhoid fevers, but this was manifestly owing to imperfection in the sewerage arrangements; and these cases afford excellent instances of the unfavourable parts badly-arranged sewers may play in this direction.*

Diarrhœa has been also reduced, but not to such an extent; and in some towns it has increased, while typhoid fever has diminished. But the term diarrhœa is so loosely used in the returns as to make any deduction uncertain. Cholera epidemics Dr Buchanan considers to have been "practically harmless." The immense significance of this statement will be at once appreciated. Whether the result is owing solely to the sewerage or to the improved water supply, which is generally obtained at the same time, is not certain. Phthisis, which Dr Buchanan and Dr Bowditch† find to be so much influenced by dampness of soil, does not appear to have been affected by the removal of excreta *per se*, at least towns such as Alnwick and Beynmawr, which are most thoroughly drained, show no lowering in the phthisical mortality. Nor could Dr Buchanan trace any effect on the other diseases of the lungs.

As far as can be seen, the effect of good sewerage has therefore been to reduce the general death rate, especially by the reduction of deaths from typhoid and from cholera (and in some towns from diarrhœa), but partly, in all probability, by general improvement of the health. The action has been, in fact, very much in the direction we might have anticipated.

It may be observed, that this inquiry does not deal with the question as between sewers and efficient dry methods of removing excreta (on which point we possess at present no evidence), but between sewerage and the old system of cesspools.

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* See the case of Worthing (p. 45), for a striking instance of the spread of typhoid through sewers.

† Ninth and Tenth Reports of the Medical Officers to the Privy Council. See especially Dr Buchanan's Report in the last-named work, p. 57. See also chapter on SOIL, p. 293.

CHAPTER XI.

AIR-PURIFIERS, SEWAGE DEODORANTS, AND DISINFECTANTS.

The term "disinfectant," which has now come into popular use, has unfortunately been employed in several senses. By some it is applied to every agent which can remove any impurity from the air;* by others, to any substance which, besides acting as an aerial purifier, can also modify chemical action, or restrain putrefaction in any substance, the effluvia from which may contaminate the air; while by a third party it is used only to designate the substances which can prevent infectious diseases from spreading, by destroying their specific poisons. This last sense is, I conceive, the most correct; and I believe it would be desirable to use the term "air purifier" in a general sense, and to restrict the term "disinfectant" to agents which are presumed to be useful in arresting the spread of those acute and so-called specific diseases which depend on the entrance into the body of a special agent *ab externo.* The exanthemata, typhus, enteric fever, relapsing fever, yellow fever, paroxysmal and remittent fevers, dengue, cholera, bubo-plague, influenza, hooping cough, diphtheria, erysipelas and dysentery (in some cases), puerperal fever, glanders, farcy, and malignant pustule, constitute the chief diseases which, we have reason to believe, are so caused.

The term disinfectant might no doubt be applied to substances nullifying the virus of syphilis, or destroying entozoa, or epiphytes, or entophytes (when these cause disease), or in similar cases; but there is a disadvantage in giving it so extended a meaning.

The substances which act as air purifiers are chiefly those employed also as disinfectants. They are used as air purifiers on the strength of some known or supposed action; as disinfectants on analogical grounds, or from evidence of actual good effect. The mode of their action as disinfectants can be only surmised, as we are entirely ignorant of the nature of any of the agencies causing the infectious diseases; it is, however, a matter of less moment to know whether disinfectants act by oxidising,† by deoxidising, by taking hydrogen or water, by restraining putrefaction or fermentation, or the development of plants or animals, or in some other way, than to be sure, that in one way or another they really do prevent an infectious disease spreading in a community.

Sub-Section I.—Air Purifiers.

The great purifying actions of Nature are diffusion, dilution, transference by winds, oxidation, and the fall of rain. Apart from agencies of this kind some effect can be produced by chemical agencies. The foreign matters in

* Tardieu, for example, Dict. d'Hyg., art. *Disinfection,* and many other authors.

† Some writers apply the term "true disinfectant" to the oxidising agents only, and refuse it to a substance which restrains putrefaction, but does not oxidise. But this is an assumption warranted by no facts.

the air, which can be removed by chemical means, are carbonic acid, sulphuretted hydrogen, ammonia (usually in the form of ammonium sulphide), and various organic substances, arising in an infinity of ways, some being odorous, others not, and of the physical and chemical nature of which little or nothing is known. Air purifiers are also used to check the growth of fungoid or infusorial organisms. They are used in the form of solids or of liquids, which may absorb the substances from the air, or of gases which may pass into the air, and there act on the gaseous or molecular impurities.

(*a.*) *Solid Air Purifiers.*—Dried earth, quicklime, charcoal, and calcium and magnesium carbolates (phenates), a mixture of lime and coal-tar, are the most important.

Of these charcoal is the most effectual. It presents an immense surface, and has a very extraordinary power of separating and absorbing gases and vapours from the atmosphere (Sennebier, quoted by Chevallier, "Traité des Désinfect," p. 146, and A. Smith), and oxidises rapidly almost every substance capable of it. Its action is not indiscriminate, but elective (A. Smith); when charcoal which has absorbed oxygen is warmed, it gives off carbonic acid (A. Smith), a proof of its great oxidising power. Exposed to the air in bags or shallow pans, its action is rapid and persistent; its effect is especially marked with sewage gases, and with the organic emanations in disease. It also absorbs sulphuretted hydrogen. Its power of purifying air from organic emanations is really great, and can be employed in hospital wards with advantage.

Of the different kinds of charcoal, the animal charcoal has the highest reputation, and then peat. But the carbon left in the distillation of Boghead coal has been stated to be even better than animal charcoal. If vegetable charcoal be used, it should be rather finely powdered. The disinfecting qualities of charcoal on air scarcely lessen with time. Charcoal filters to be placed before the mouth have been recommended by Stenhouse, and might be useful in cases of very impure air. Dried marly earth is much inferior to charcoal, but still can be employed in the absence of the latter.

Quicklime absorbs carbonic acid, and perhaps compounds of sulphur, and has been employed for that purpose.

Lime and magnesium carbolates have been also used; their exact effect on the air passing over them is not, I believe, known; but as they give off carbolic acid, their action may be chiefly in that way.

(*b.*) *Liquid Air Purifiers.*—Solutions of potassium permanganate (Condy's red fluid), zinc chloride, and lead nitrate are sometimes used, being either exposed in flat dishes, or cloths are dipped in the solution and exposed to the air. They act only on the air which comes in contact with them, but in that way absorb a good deal. Condy's fluid, when well exposed to the air, seems to have a purifying effect, and to lessen the close smell of ill-ventilated rooms, while the nitrate of lead absorbs sulphuretted hydrogen.

Lime and soda chlorides, nitrous acid, solution of sulphurous acid, pyroligneous acid, act on the air chiefly or entirely by the gases which pass off from them, and their effects are considered under that head.

(*c.*) *Gaseous Air Purifiers.*—The evolution of gases into the air is the most powerful means of purifying it independent of ventilation. The principal gases are ozone, chlorine, iodine, bromine, nitrous, sulphurous, and hydrochloric acids, carbolic acids, tar fumes, acetic acid, ammonia.

Ozone.—It has been proposed to disengage ozone constantly into the air of a room, by heating a platinum wire by a Bunsen cell, or by half immersing a stick of phosphorus in water in a wide-mouthed bottle; the amount of ozone can be measured by the common ozone paper, and the stopper put in if the

tint is too deep. It is presumed it will then act as a powerful or oxidising agency, and destroy organic matter.

Chlorine.—Given off from chloride of lime, moistened with water, or with dilute sulphuric acid, and placed in shallow vessels, or from chloride of soda, or evolved at once. Four parts by weight of strong hydrochloric acid are poured on one part of powdered binoxide of manganese, or four parts of common salt and one part binoxide of manganese are mixed with two parts by weight of sulphuric acid and two of water, and heated gently. According to the size of the room, the actual weight of the substances taken must vary. Or two table-spoonfuls of common salt, two tea-spoonfuls of red lead, half a wine-glassful of sulphuric acid, and a quart of water are taken. Mix the lead and salt with the water, stir well, and add the sulphuric acid gradually. Chlorine is evolved, and is absorbed by the water, from which it is slowly driven out. It may be kept in a jar or stoppered bottle, left open as occasion may require.*

Chlorine decomposes sulphuretted hydrogen and ammonium sulphide at once, and more certainly than any other gas. It doubtless destroys organic matter in the air, as it bleaches organic pigments, and destroys odours, either by abstracting hydrogen, or by indirectly oxidising. Euchlorine, a mixture of chlorous acid and free chlorine, and obtained by gently heating (by placing the saucer in warm water), a mixture of hydrochloric acid and potassium chlorate, has been also used instead of pure chlorine. Its odour is different and not so quite unpleasant, but whether it is superior or not I do not know. It must be made on the small scale, as with a high temperature it explodes.

Iodine can be easily diffused through the atmosphere by placing a small quantity on a hot plate. Dr Richardson proposes to saturate a solution of peroxide of hydrogen with iodine, and to add $2\frac{1}{2}$ per cent. of sea-salt; by "atomising" or "pulverising" the fluid by the little instrument used for this purpose, the air can be charged with iodine and sea-salt spray very readily. Iodine will decompose SH_2, and destroys, therefore, much odour. Its action was investigated by Duroy in 1854,† who showed that it is a powerful arrester of putrefaction. As it condenses easily, and does not diffuse everywhere like chlorine, it might be expected to be less useful than chlorine.

Bromine.—In the American civil war bromine was rather largely used as an aerial disinfectant; a solution of bromine in bromide of potassium is placed in saucers and exposed to the air; the vapour is, however, very irritating, and should not be disengaged in too large an amount.

Nitrous Acid can be evolved by putting a bit of copper in nitric acid and a little water. The nitrogen dioxide which is given off takes oxygen from the air, and red fumes, consisting chiefly of nitrogen tetroxide or nitrous acid (N_2O_4), are formed.

The oxidising action of nitrous acid is very great on organic matter. It removes the smell of the dead-house sooner than any other gas. It is rather irritating to the lungs, and, in some persons, large quantities of it cause vertigo, nausea, and even vomiting. If possible, when it is used, the rooms should be cleared; if not, it should be disengaged slowly, which can always be done by diluting the nitric acid.

The action of nitrous acid results from the ease with which it parts with oxygen to any oxidisable substance, being converted into nitrogen dioxide, which again at once combines with atmospheric oxygen, and so on.

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* Medlock's "Record of Pharmacy and Therapeutics," 1858, p. 20.
† Chevallier, Traité des Désinfect, p. 19.

Sulphurous Acid.—Most easily evolved by burning sulphur. It decomposes sulphuretted hydrogen ($SO_2 + 2SH_2 = 3S + 2OH_2$), and also combines with ammonia. It has also been supposed to act powerfully upon organic matter (Graham), and probably does so if ammonia is not present. Guyton-de-Morveau, who studied the action of this acid, was of opinion that it completely disinfects miasms, and gives some evidence on this point.

Hydrochloric Acid.—The fumes of this acid were used by Guyton-de-Morveau, and at one time they were much employed, but the action of chlorine is so much more powerful that they are now seldom used.

Carbolic Acid.—This substance is given off when solid carbolic acid is placed in a saucer, or when the liquid acid and water is sprinkled about, or still better, when one part of the acid and two of ether is allowed to evaporate. It conceals all odours, and arrests, it is to be presumed, the putrefactive changes in floating organic matters and the growth of fungi. It is difficult to measure its action, as it decomposes solution of potassium permanganate, which cannot therefore be used as a measure of the organic impurity of air when carbolic acid vapours are present.

Coal-Tar and Bitumen Fumes.—This is an old plan much used in the last century; the fumes contain carbolic and cresylic acids with other substances, and it is presumed have the same effect as carbolic acid. The substance employed by Süvern, and which has at present some reputation in Germany, owes its success as an air-purifier to the fumes of coal-tar.

Vinegar and Ammonia.—The vapour of vinegar is an old remedy, and was much employed by Howard in the purification of gaols; the efficient agents were probably heat and ventilation, which Howard made use of at the same time. The vinegar would, of course, neutralise any ammoniacal vapours which might be in the air; whether its action would extend beyond this is doubtful.

A mixture of 1 part of carbolic and 9 of vinegar, and a little camphor, has been used as a disinfectant in cabins on board ship.

The vapour of ammonia would not *a priori* seem likely to be a purifier, though, as it restrains decomposition in solid matters, its vapour may have an effect in the air.

It will be observed that the chief gases attacked by the air-purifiers are sulphuretted hydrogen and ammonium sulphide, which are easily destroyed by several agents, especially by chlorine, iodine, and sulphurous acid gas.

The opinion that the floating organic vapours or molecules of whatever kind in the air are destroyed by the air-purifiers, has been hitherto derived not from direct quantitive determination of the organic matter before and after the action of the purifiers, but from their influence on odours and on other organic substances where their action is more easily followed. But the analogical evidence is so strong that we can have little doubt of the reality of the action.

The mode of action of the air-purifiers may be conceived to vary. Ozone and nitrous acid will directly oxidise all substances which can be so acted upon. Chlorine may act by substitution for hydrogen, or it may take hydrogen and oxidise indirectly by liberating oxygen; bromine and iodine may also take hydrogen in the same way. Sulphurous acid more probably deoxidises and forms sulphuric acid. In other cases, it seems probable that neither substitution nor oxidation nor the reverse takes places, but that the action is one of restraint of putrefaction and of limitation of the growth of cryptogamic life. At least this may be inferred from the experiments of Crooks, Lemaire, and others on the action of carbolic acid on low forms of life growing in liquids.

If the observations of Trautman* (see page 116) on the rapid growth of "decomposition cells" are correct (and previous observations certainly render them probable), the influence of carbolic acid vapours on the growth of cells in the air is certain. The water condensed from a room with six men in it, and without ventilation, had a disagreeable smell, and contained quantities of bacteria and cell-heaps; some of the cells were commencing to divide, and this process much increased after some hours. The water condensed subsequently from the air of some rooms under similar conditions, but with carbolic acid and ether diffused through it, had a smell of carbolic acid; a few round and oval cells were seen, but no bacteria or cell-heaps, as in the former case; so that it seemed clear that carbolic acid, although it did not perfectly arrest, yet restricted the growth of the cells. A second experiment gave similar results. Tar fumes alone had very little effect, but when 1 part of lime was mixed with 10 parts of coal-tar, the effect on the atmospheric "decomposition-cells" was very marked, and even exceeded that of carbolic acid.

Sub-Section II.—Sewage Deodorants.

A very great number of substances have been added to sewage for the purpose of preventing decomposition and retaining the ammoniacal compounds.

1. Charcoal—which soon, however, gets clogged and loses its power—it is not nearly so useful when used in this way as in the purification of air. Sillar's preparation (the A. B. C. deodorant) is a mixture of animal charcoal, blood, clay, and alum refuse.

2. Dry earth, especially, as already noticed, marly and clayey soils; the effect is similar to charcoal, but it is not so soon clogged. Dr Bird's preparation is ferruginous clay moistened with sulphuric acid, and then dried and pulverised. It is said to have a good effect.

3. Quicklime and water added till a deposit occurs, leaving a clear fluid above. This is chiefly caused by the lime forming insoluble salts, by union with carbonic and phosphoric acids, and mechanically carrying down the suspended matters. The sulphuretted hydrogen forms calcium sulphide, which remains in the supernatant fluid. The ammonia is set free. The potash salts remain in the liquid. Five-sixths of the phosphoric acid are in the precipitate. No organic matter is precipitated except mechanically. The solid deposit has little value as manure. The lime delays, but does not prevent the subsequent decomposition of the animal and vegetable matters, and as the calcium sulphide easily decomposes, sulphuretted hydrogen is very liable to be again set free from the clear fluid.

The process, though simple and cheap, is by no means perfect. The addition of charcoal to the lime does not materially modify the result.

From 15 to 16 grains of quicklime are enough for 1 gallon of sewage, or 20 cwt. per million gallons. At Leicester 580 tons of quicklime were used per annum for 4,700,000 tons of sewage.

4. Cheap salts of alumina, and then lime, or alum sludge, lime, and waste animal charcoal (Manning), or zinc and charcoal (Stothert's process), alum, blood, and bone black (Sillar's process).

The alumina precipitated by the lime forms a very bulky precipitate, well suited to the entanglement of suspended matters. The clearance of the sewage is more perfect than with lime alone, but otherwise the process and the objections are the same, and the cost is greater. The whole of the phos-

* Die Zersetzungsgase, von Dr Trautman, 1869, p. 51, *et seq.* I do not know how far we can apply Trautman's experiments, on the hindered growth of cells in urine, &c., to the case of air, so I have not referred to them.

phoric acid is precipitated as phosphate of alumina. To a gallon of sewage-water were added $73\frac{1}{2}$ grains of sulphate of alumina, $3\frac{1}{2}$ grains of sulphate of zinc, $73\frac{1}{2}$ grains of charcoal, $16\frac{3}{4}$ grains of quicklime.

5. Superphosphate of magnesia, and lime water (Blyth's patent). The idea was to add a substance which, in addition to deodorising, might be useful as a manure, and it was thought that a double phosphate of magnesia and ammonia would be thrown down; but this salt is sufficiently soluble in water, especially when the water contains chloride of sodium, to render this expectation incorrect. This method has been practically found to be useless, and to be more costly than any other plan.

6. Iron Perchloride.—When this salt is added to sewage, a precipitate of ferric iron is caused by the ammonium carbonate (which forms so rapidly in sewage), and carries with it all the suspended matters of the sewage. A clear fluid remains above. The sulphuretted hydrogen falls in the precipitate as iron sulphide. As the sulphide of iron tends to form ferric oxide, sulphur being let free, it has been conjectured by Hofmann that an oxidising effect from the oxide may follow the first action.

Both precipitate and supernatant liquid are free from odour.

This substance has been tried at Croydon and Coventry. From 14 to 29 grains per gallon of sewage are necessary for London sewage; for Croydon sewage from 5 to 15 grains were necessary. One gallon of liquid perchloride was sufficient for 15,000 gallons of sewage (Hofmann and Frankland).

The perchlorides of iron can be manufactured by dissolving peroxide of iron in hydrochloric acid; the different iron ores, refuse oxide of iron from sulphuric acid works, iron rust in foundries, &c. Another plan is to take equivalent proportions of common salt, sulphuric acid, iron rust, and water, so that chlorine, when disengaged, shall combine with the iron. A hard, yellowish, not very deliquescent substance, containing 26 per cent. of perchloride of iron, is formed, which can be transported to any distance. The price, if made in this way, is L.2, 7s. per ton (cost of labour not included) in England.

The perchloride acts both on sulphuretted hydrogen and on sulphides, in both cases setting free sulphur. In sewage its ordinary action is on sulphide of ammonium.

Objections have been made to the perchloride, as it contains arsenic; but the amount of this is small, and as it falls with the deposit it is never likely to be dangerous.

7. Lead Nitrate, or Ledoyen's Fluid, is made by dissolving 1 ℔ of litharge in about 7 ounces of strong nitric acid and 2 gallons of water; a little of the water is mixed with the litharge; the acid is gradually added, and then the rest of the water. This quantity will deodorise a moderate-sized cesspool. It acts rapidly on sulphuretted hydrogen, and can be depended upon for this purpose.

8. Zinc Chloride.— Burnett's fluid contains 25 grains to every fluid drachm; 1 pint is added to a gallon of water (1 to 8). It is usually said to decompose sulphuretted hydrogen until the solution becomes acid, when its action ceases; but Hofmann finds that it does not act on free sulphuretted hydrogen, but on ammonium sulphide, forming zinc sulphide and ammonium chloride. It destroys ammoniacal compounds and organic matter. The sulphates of zinc and copper decompose free sulphuretted hydrogen, with formation of metallic sulphide and water.

Burnett's fluid delays decomposition in sewage for some time, and prevents the acidity of urine; but a very peculiar odour is given out, showing that some change is going on. A good effect is produced on sulphuretted hydrogen by a mixture of zinc and ferrous sulphate (Larnaudes' mixture), which also lessens for the time the peculiar sewage smell.

9. Potassium permanganate prevents putrefaction for a short time, and removes the odour from putrefying sewage, but it requires to be used in large quantity. It has been proposed to use it and ferrous sulphate, first to oxidise and then to restrain alkalinity; the way of doing this is to add the permanganate to the sewage first, and let it oxidise as far as it can, and then to add the ferrous sulphate, so as to remove the chance of action on the permanganate by the sulphate. But this plan has not succeeded in my hands. Although the large quantity of the permanganate which must be used makes it a bad sewage deodorant, it has certainly a considerable action on fermenting liquids; and it might be useful to try its effect with cholera dejections, either alone, or, as Kühne recommends, with ferric sulphate, which will not be acted on by the permanganate like the green vitriol.

10. Preparations from coal-tar; carbolic acid (phenol or phenic acid, or phenyl-alcohol; coal-tar creosote (C_6H_6O)), and cresylic acid (cresol or cresyl-alcohol, C_7H_8O), in various admixtures.* These substances are the best sewage deodorants and arresters of putrefaction that exist.

The last few years have seen an extraordinary development in the manufacture of these substances. Phenol or carbolic acid is now obtained in great purity, and is sold in crystals, and also in a liquid form. All the preparations may be conveniently classed under the three divisions of crystals, liquids, and powders.

(*a.*) *Crystals.*—Carbolic acid, more or less pure, is the only substance under this head; it is so slightly soluble in water that it is not so useful as a deodorant as the impurer kind. When mixed with sewage it acts slowly and not so perfectly as the impurer kinds. When exposed to the air it liquefies, and is slowly given out into the air, and is then supposed to be useful as an air purifier.

(*b.*) *Liquids.*—Carbolic acid, more or less impure, dissolved in water, simply, or with a little alcohol and cresylic acid (cresol), forms the liquid carbolic acids. In the market they are found almost colourless, or highly coloured. The various liquids contain from 10 to 90 per cent. of phenol. Cresol, though crystalline and colourless when pure, is usually found in the market as a dark liquid. Some of it no doubt exists in most samples of carbolic acid. Owing probably to the way they mix at once with the sewage, the liquid acids are more deodorant than the crystallised acid, and restrain putrefaction for a long time.

Sometimes samples of so-called carbolic acid are sold, which are only impure tar oils, and almost destitute of deodorising power. Sometimes a nauseous sulphur compound is also present.

Mr Crookes† gives the following rules in order to determine the presence of the tar oils:—

"Commercial carbolic acid is soluble in from 20 to 70 parts of water, or in twice its bulk of a solution of caustic soda, while oil of tar is nearly insoluble, but if the amount of carbolic acid be increased, soda remains undissolved."

"To apply the tests—1. Put a teaspoonful of the carbolic acid in a bottle, pour on it half a pint of warm water, and shake the bottle at intervals for half an hour, when the amount of oily residue will show the impurity; or dissolve one part of caustic soda in 10 parts of warm water, and shake it up with 5 parts of the carbolic acid. As before, the residue will show the amount of impurity."

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* It is perhaps unfortunate that phenol and cresol, which are rather alcohols than acids, should have been termed carbolic and cresylic acids. If the terms phenol and cresol could be used instead, it would be better. But I have thought it better not to abandon at present terms which have got into general use.

† Third Report—Cattle Plague Commission.

"These tests will show whether tar oils have been used as adulterants, but to ascertain whether the liquid consists of a mere solution of carbolic acid in water or alkali, or whether it contains sulpho-carbolic or sulpho-cresylic acids, another test must be used based on the solubility of these, and the insolubility of carbolic acid in a small quantity of water. In this case proceed as follows:—2. Put a wineglassful of the liquid to be tested in a bottle, and pour on it half a pint of warm water. If the greater part dissolves, it is an adulterated article. Test the liquid in the bottle with litmus paper; if strongly acid, it will show the probable presence of sulpho-acids; whilst if alkaline, it will show that caustic soda has been probably used as a solvent."

If the quantity of carbolic acid has to be estimated from a liquid, it must be distilled at a given temperature. Carbolic acid boils at 184° C. (= 363 Fahr.), cresol at 203° C. (= 397·4 Fahr.)

In using the liquid acid, 1 part is mixed with 50 or 100 of water, according to the strength of the acid, and thrown down drains or into cesspools, or sprinkled with a watering-can over dung-heaps.

(c.) *Powders.*—The two principal carbolic acid powders are M'Dougall's and Calvert's, but there are several others in the market known under various names.

M'Dougall's and Calvert's powders are widely different in composition.

The former is strongly alkaline from lime, and makes the sewage alkaline. It consists of about 33 per cent. of carbolate of lime and 59 per cent. of sulphite of magnesia, the rest being water.

Calvert's powder is carbolic acid, about 20 to 30 per cent., mixed with alumina from alum works, and some silica.

The quantity of these preparations which must be used depends on the degree and duration of deodorisation wished for. For the daily solid excreta (4 ounces) of an adult at least from 30 to 60 grains of the crystallised acid, 60 drops of the strong liquid (90 per cent. of acid), or $\frac{1}{2}$ ounce of the dilute carbolic acid, sold at 1s. per pint, are necessary, if the sewage is to be kept in an unaltered state for 10 to 20 days, but a smaller amount is sufficient for 2 or 3 days.* Half an ounce of either Calvert's or M'Dougall's powder for 4 ounces of sewage has a preservative effect for 18 to 21 days; $\frac{1}{4}$ ounce or less is effectual for 3 or 4 days.

Smaller quantities can, however, be used, if diminution, but not entire removal of smell and putrefaction is desired.

11. *The Süvern Deodorant.*—The water flowing from sugar factories has long been a source of annoyance and ill-health; it contains quantities of vegetable organisms (Oscillaria alba or Beggiatoa), which act like ferments, and rapidly decompose the sulphates in the water, and liberate sulphuretted hydrogen. Herr Süvern, to remedy this, proposed a preparation of coal-tar thus prepared.† A bushel and a half of good quicklime are put in a cask and slaked; it is well stirred, and 10 ℔ of coal-tar are thoroughly mixed with it, so that the coal tar may be thoroughly divided. Fifteen pounds of magnesium chloride dissolved in hot water are then thoroughly mixed with the mass, and then additional hot water is added, sufficient to make a mass of just sufficient liquidity to drop slowly from a stick inserted in it and then pulled out. The effect of the magnesium chloride is this,—it forms deliquescent calcium chloride, magnesia being liberated, and it is found that this prevents the caking of the deodorant and the adherence to pipes, which is a defect

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* See my experiments in the Army Medical Department Report, vol. viii. p. 318. Dr Squibb (on the Alcohols from Coal-Tar, Phil. 1869) has given some experiments to show that cresol is twice as powerful as phenol in its destructive action on cryptogams. This accords with my experiments, that the impure acids are more powerful deodorants than the pure.

† Trautman, Die Zersetzungsgase, 1869, p. 35.

when lime alone is used. This deodorant has come into considerable use for cesspools, drains, &c.

General Conclusion.—On the whole, the carbolic acid and the preparations appear the most generally useful as sewage deodorants, or the Süvern deodorant, and after them the ferric chloride ($Fe_2\ Cl_6$). As precipitants for water sewage the mixtures of lime and alum sludge appear the best. Bird's sulphated clay and Sillar's compound of charcoal, blood, and alum, have been favourably spoken of, but require more investigation.

Army Regulations on the Subject of Sewage Deodorants.

By a memorandum issued December 1867 (clause 92), a requisition for disinfectants is, in case of emergency, to be approved by the principal medical officer of the district, and sanctioned by the general in command. It is then supplied by the Barrack Department.

The disinfectant recommended is one of the carbolic acid powders.

In time of cholera the following substances are ordered to be used:—Quicklime, carbolic acid, chloride of lime, and common commercial perchloride of iron.—(Cholera Instructions, Nov. 1867, clause 83; Army Medical Department Report, vol. viii. p. 638.)

One hundred gallons of weak carbolic acid, containing one gallon of concentrated acid, are considered to be enough for daily use in a barrack containing one or two regiments.

Sub-Section III.—Disinfectants.

That a substance can act as a disinfectant, in the sense in which the word is used here, can be known only from observation and proof from evidence in each disease, and, unfortunately, this is not easy to get. There are some difficulties also in employing the most powerful air-purifiers. If we are right in supposing that from the bodies of persons suffering from contagious diseases (such as smallpox, scarlet fever, measles, typhus, &c.) quantities of matter are passing into the air which are capable of exciting the same diseases in other persons if they find a proper nidus, it is evident that, if disinfectants are to act effectively, they must be continually in the air. The particles of such poison passing off ought at once to meet with the particles of the agent which are to destroy them. But a difficulty arises in keeping the air constantly charged with chlorine, and still more with the fumes of sulphurous or nitrous acids, as they are irritating to the lungs; and yet occasional disinfection can be of little service. This consideration renders it of great importance to know whether ozone and carbolic acid or tar vapours really have the power ascribed to them, since these substances are not irritating in moderate quantities, and can do no harm when breathed. Of the three gases named, chlorine is on the whole the least irritating, and therefore it is more adapted for disinfection in rooms where the sick are, while nitrous and sulphurous acid gases are better adapted for the fumigation of empty rooms, where any quantity of the gas may be poured into and retained in the air.

In the case of diseases which, like cholera and enteric fever, are believed to be propagated by the emanations from the discharges (and indeed in all cases), the disinfectant has to be applied very carefully, and at once, to the discharges when passed.

In the case of scarlet fever, where the poison is supposed to exist (principally at any rate) in the skin, the ingenious suggestion has been made by Dr William Budd to prevent the poison passing into the air, and hinder the

cuticular particles from floating away, by covering the whole surface with camphorated oil; and he has given some evidence in support of the efficacy of this plan. It might be desirable in this and the similar cases of smallpox and measles to bring the disinfectant at once in contact with cutaneous discharges, and the combinations of weak carbolic acid and glycerine seem well adapted to test this possible means of prevention. In typhus and plague, as the poison is supposed to pass off both from the skin and lungs, not only might the skin be purified by such an application, and by washing with carbolic acid soap, but a vessel containing an aerial disinfectant might be suspended a short distance above the head of the patient, so that, without annoyance to him, his breath ascending would meet at once with the gas which, it is supposed, will destroy the organic particles of the contagion.

For aerial use in the sick-room, chlorine disengaged in the way already noted, and kept within moderate limits, and carbolic acid vapours, are the most readily available. Hypochlorous acid (euchlorine) has been also strongly recommended.

Disinfection of Clothes.

Heat.—For complete disinfection, whether clothes or bed-linen require to be purified, it is probable that there is no agent so certain as heat. Dr Henry of Manchester,* after showing that vaccine matter lost its power if heated to 140° Fahr. for three hours, proposed to disinfect clothing by dry heat. He disinfected scarlet fever clothing by exposure to 212° Fahr. for one hour; woollen clothing from plague patients, after being heated 24 hours from 144° to 167° Fahr., was worn with impunity by 56 healthy persons for 14 days. Heat has also been largely used to disinfect clothing by the Americans in their civil war, both in the form of dry heat and boiling water. It is believed that the cessation of the plague in Egypt, after St John's day, is due to the increased heat of the air; but possibly the hygrometric condition of the air may have more to do with this. It has also been surmised that the yellow fever poison is destroyed by an intense heat. Dr Shaw has collected the few facts which we know on this subject.†

The best mode of dry heating is by an arrangement something like the chamber used for drying clothes—the heat, however, may be carried rather higher. A common oven, which can be easily heated to 260° or 300°, will also answer very well on a small scale. Fumigation with sulphurous acid gas can be combined with heating in this way.

Chloride of Lime Water.—In addition to, or in place of heat, the clothes should be plunged in water containing 1 gallon of strong solution of chloride of lime to 20 or 30 gallons of water; the same solution can be used two or three times, then the clothes should be boiled. This plan is, however, more expensive than the plan by dry heat.

Disinfection in various Diseases.

Smallpox—Measles—Scarlet Fever.—In all these diseases it is now customary to employ disinfectants, especially chlorine, disengaged continually in small quantities. I have been unable to find any facts which can be relied on in proof that the spread of the diseases was really arrested; but it is obvious how much difficulty must exist in obtaining unequivocal evidence of this kind, and this should not lead to a disregard of the precaution. Iodine instead of chlorine has been advised by Dr Richardson and Mr Hoffman,‡

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* Philosophical Magazine, 1863, 1-32.
† Trans. Soc. Science Assoc. for 1861, p. 558.
‡ British Medical Journal, Dec. 1863.

but whether it is more powerful or more convenient than chlorine is uncertain. Allusion has already been made to the plan of applying substances to the skin to arrest or destroy the poison; as a matter of precaution it would be well to use them for all the excretions. For this latter purpose carbolic acid is probably the best.

Typhus (*exanthematicus*).—The nitrous acid fumes were tried very largely towards the close of the last century and the beginning of this, in the hulks and prisons where Spanish, French, and Russian prisoners of war were confined.* At that time, so rapidly did the disease spead in the confined spaces, where so many men were kept, that the efficacy even of ventilation was doubted, though there can be no question that the amount of ventilation which was necessary was very much underrated. Both at Winchester and Sheerness the circumstances were most difficult; at the latter place (in 1785), in the hulk, 200 men, 150 of whom had typhus, were closely crowded together; 10 females and 24 men of the crew were attacked; 3 medical officers had died when the experiments commenced. After the fumigations, one attendant only was attacked, and it appeared as if the disease in those already suffering became milder. In 1797 it was again tried with success, and many reports were made on the subject by army and naval surgeons. It was subsequently largely employed on the Continent,† and everywhere seems to have been useful.

These facts lead to the inference that the evolution of nitrous acid should be practised in typhus fever wards, proper precautions being taken to diffuse it equally through the room, and in a highly dilute form.

Hydrochloric acid was employed for the same purpose by Guyton-de-Morveau, in 1773, but it is doubtless much inferior to nitrous acid. Chlorine has been also employed, and apparently with good results.‡

Yellow Fever.—Fumigations of nitrous acid were employed by Ramon da Luna,§ and it is asserted that no agent was so effectual in arresting the spread of the disease.

Dysentery.—It is well known that dysentery, and especially the putrid dysentery, may spread through an hospital from the practice of the same close stool or latrines being used. As long ago as 1807 fumigations of chlorine were used by Mojon,‖ to destroy the emanations from the stools, and with the best effects.

Cholera.—Chlorine gas, diffused in the air, was tried very largely in Austria and Hungary in 1832, but without any good results. Nitrous acid gas was used at Malta in 1865, but apparently did not have any decided influences, although Ramon da Luna has asserted that it has a decided preservative effect, and that no one was attacked in Madrid who used fumigations of nitrous acid. But negative evidence of this kind is always doubtful. Charcoal in bulk appears to have no effect; Dr Sutherland saw a ship's crew severely attacked, although the ship was loaded with charcoal.

Carbolic acid vapour diffused in the atmosphere was largely used in 1866

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* It was used at Winchester in 1780 by Carmichael Smith, and again at Sheerness in 1785. Smith published several accounts:—"An account of the experiment made at the desire of the Lords Commissioners of the Admiralty. By J. C. Smith, 1796."

† Chevallier, Traité des Désinfectants, pp. 39, 40. ‡ Ibid., pp. 14, 15.

§ Ann. d'Hygiène, Avril 1861.

‖ His words, as quoted by Chevallier, are interesting:—"The dysentery became contagious in the hospital at Genoa; almost all the sick of my division, nearly 200, were attacked; and, as we know that this disease, when contagious, is communicated ordinarily from one person to another by the abuse which exists in all hospitals of making the same latrines serve for all the sick of a ward, I wished to see if fumigations of chlorine had the power of destroying these contagious exhalations. I therefore caused fumigations to be used twice daily in the latrines, and, in a few days, I was able to destroy that terrible scourge, which already had made some victims." It appears that the chlorine was therefore in the air, and not added to the stools.

in England; the liquid was sprinkled about the water, and sawdust moistened with it was laid on the floors and under the patients. The effect in preventing the spread of the disease was very uncertain.

Disinfectants have been added to the choleraic discharges, and it is most desirable that this should be a constant practice, although the evidence of its utility in the last European epidemic is discordant.

The ferrous sulphate (green vitriol) which has been strongly recommended by Pettenkofer as an addition to the cholera evacuations, was fully tried in 1866 at Frankfurt, Halle, Leipzig, in Germany, and at Pill near Bristol,* and in those cases without any good result. In other places, as at Baden, the benefit was doubtful. It seemed to answer better with Dr Budd and Mr Davies at Bristol, but other substances were also used, viz., chlorine gas in the rooms, and chloride of lime and Condy's fluid for the linen. On the whole it seems to have been a failure.† Ferric sulphate, with or without potassium permanganate, has been recommended by Kühne instead of ferrous sulphate, but I am not aware of any evidence on the point. Carbolic acid was largely used in England in 1866, and appeared in some cases to be of use, as at Pill, near Bristol, and perhaps in Southampton. It failed at Erfurt, but as it is believed the wells were contaminated by soakage‡ this is perhaps no certain case. Chloride of lime and lime were used at Stettin without any good result, and on the whole, it may be said that the so-called disinfection of the discharges of cholera does not seem to have been attended with very marked results. At the same time, it cannot be for a moment contended that the plan has had a fair trial, and we can easily believe that unless there is a full understanding on the part of both medical men and the public, of what is to be accomplished by this system, and a conscientious carrying out of the plan to its minutest details, no safe opinion of its efficacy or otherwise can be arrived at.

Cattle Plague.—The experiments made by Mr Crookes§ on the disinfectant treatment of cattle plague with carbolic acid vapour have an important bearing on human disease. Although the observations fall short of demonstration, there are grounds for thinking that when the air was kept constantly filled with carbolic acid vapour, the disease did not spread. As such experiments are very much more easily carried out on the diseases of animals than on those of men, it is much to be wished that the precise effect of the so-called disinfectants should be tested by continuing the experiments commenced by Mr Crookes, not only in cattle plague in the countries where it prevails, but in epizootic diseases generally.

It may be said in conclusion, that although positive evidence is so deficient, yet taking into consideration the decidedly great and known effect of many of the air-purifiers on organic matters, and the fact that the infectious organic agencies are certainly easily destroyed in most cases (since free ventilation renders many of them inert, and few of them retain their power very long), it is highly probable that the specific poisons of the so called zymotic diseases are destroyed by some of these agents, and, at any rate, the careful and constant use of the most efficient air-purifiers is not only warranted but should be considered imperative.

* Tibbets, "Medical Times and Gazette," October 1867.

† In my experiments on sewage putrefaction (Army Med. Reports, vol. viii. p. 318), ferrous sulphate had very little action in preventing putrefaction, and the Committee of the Berlin Medical Society declined to recommend it for cholera, as they found it did not prevent fermentative action.

‡ Ninth Report of the Medical Officer to the Privy Council, p. 31.

§ Third Report of the Cattle Plague Commission, Appendix, 1866.

CHAPTER XII.

WARMING OF BARRACKS AND HOSPITALS.

The heat of the human body can be preserved in two ways:—

1. The heat generated in the body, and which is continually radiating and being carried away by moving air, can be retained and economised by clothes. If the food be sufficient, and the skin can thus be kept warm, there is no doubt that the body can develop and retain its vigour with little external warmth. In fact, provided the degree of external cold be not too great (when, however, it may act in part by rendering the procuring of food difficult and precarious), it would seem that cold does not imply deficiency of bodily health, for some of the most vigorous races inhabit the cold countries. In temperate climates there is also a general impression (and such general impressions are often right) that for healthy adults external cold is invigorating, provided food be sufficient, and if the internal warmth of the body is retained by clothing.

2. External heat can be applied to the body either by the heat of the sun (the great fountain of all physical force, and vivifier of life), or by artificial means, and in all cold countries artificial warming of habitations is used.

The points to determine in respect of habitations are—

1*st*, What degree of artificial warmth should be given?

2*d*, What are the different kinds of warmth, and how are they to be given?

SECTION I.

DEGREE OF WARMTH.

For Healthy Persons.—There appears no doubt that both infants and old persons require much artificial warmth, in addition even to abundant clothes and food. The lowering of the external temperature, especially when rapid, acts very depressingly on the very young and old; and when we remember the extraordinary vivifying effect of warmth, we cannot be surprised at this.*

For adult men of the soldier's age, who are properly fed and clothed, it is probable that the degree of temperature of the house is not very material, and that it is chiefly to be regulated by what is comfortable. Any temperature over 48° up to 60° is felt as comfortable, though this is dependent in part on the temperature of the external air. It seems certain that for healthy well-clothed and well-fed men we need not give ourselves any great concern about the precise degree of warmth.

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* Inanition experiments on animals prove how death may be retarded by applying warmth; and Valentin's experiments on killing animals by coating their skins with an impermeable cement show the same thing even more forcibly. Such animals, even when at the point of death, were wonderfully resuscitated by warmth, a good hint to us to employ this powerful agent in appropriate cases.

For children and aged persons we are not, I believe, prepared to fix any exact temperature; for new-born children a temperature of 65° to 70°, or even more, may be necessary, and old people bear with benefit a still higher warmth.*

For Sick Persons.—The degree of temperature for sick persons is a matter of great importance, which requires more investigation than it has received. There seems a sort of general rule that the air of a sick-room or hospital should be about 60° Fahr., and in most continental hospitals, warmed artificially, this is the contract temperature; but the propriety of this may be questioned.†

There are many diseases greatly benefited by a low temperature, especially all those with preternatural heat. It applies, I believe, almost without exception (scarlet fever?) to the febrile cases in the acute stage, that it is desirable to have the temperature of the air as low as 50° or even 45° or 40°. Cold air moving over the body is a cooling agent of great power, second only, if second, to cold affusion, nor is there danger of bad results if the movement is not too great. The Austrian experiments on tent hospitals‡ show conclusively that even considerable cold is well borne.

Even in the acute lung affections this is the case. Pneumonia cases do best in cold wards, provided there is no great current of air over them.

Many cases of phthisis bear cool air, and even transitions of temperature, well, provided there be no great movement of air.

On the other hand, it has appeared to me that chronic heart-diseases with lung congestion, emphysema of the lungs, and diseases of the same class, require a warm air, and perhaps a moist one. I have noticed that patients with these affections, when removed from their own houses with hot rooms to the comparatively cool and ventilated wards of a London hospital, were often injured.

With respect to the inflammatory affections of the throat, larynx, and trachea, I have no decided evidence of my own, and have been able to find nothing decisive in authors on this point; but the spasmodic affections of both larynx and bronchial tubes seem benefited by warmth.

In the convalescence, also, from acute diseases, cold is very badly borne; no doubt, the body, after the previous rapid metamorphosis, is in a state very susceptible to cold, and, like the body of the infant, resists external influences badly. Convalescents from fever must therefore be always kept warm. This is probably the reason why, in the Austrian experience,§ it has been found inadvisable to transfer febrile patients treated in a permanent hospital to convalescent tents, although patients treated from the first in tents have a good convalescence in them, as if there were something in habit.

If these views are correct, they show that hospitals should have wards of different temperatures. The plan of ventilation already noted, viz., heating fresh air under each bed by hot-water pipes (the passage of hot water through certain of which can be stopped if desired), offers a means of giving a certain temperature to a bed even in a large ward, or in a small ward of bringing the whole air in the ward to any desired temperature.

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* It is singular, however, that in some old people the temperature of the body is higher than normal (John Davy). Is there, then, a difference in the amount of external heat required in different persons?

† It is owing to this rule that in French hospitals, artificially ventilated and warmed by hot air, the amount of air is lessened and its temperature heightened in order to keep up the contract temperature of 15° C. (= 59° F.) The air is often then close and disagreeable.

‡ See Report on Hygiene in the Army Medical Report for 1862, by the author.—*Blue-Book*, 1864. The Prussians have also lately made great use of tents in the summer.

§ Das Kranken-Zerstreuung's System, von F. Kraus, 1861.

SECTION II.

DIFFERENT KINDS OF WARMTH.

Heat is communicated by radiation, conduction, and convection. The latter term is applied to the conveyance from one place to another of heat by means of masses of air, while conduction is the passage of heat from one particle to another—a very slow process. Practically, conduction and convection may be both considered under the head of convection.

Radiant heat has been considered by most writers the best means of warming; it heats the body without heating the air,* and of course there is no possibility of impurity being added to the air.

The disadvantages of radiant heat are its cost, and its feebleness at any distance. The cost can be lessened by proper arrangement, but the loss of heat by distance is irremediable. The effect lessens as the square of the distance, *i.e.*, if at 1 foot distance from the fire, the warming effect is said to be equal to 1, at 4 feet distance it will be sixteen times less. A long room, therefore, can never be warmed properly by radiation.

It has been attempted to calculate the amount of air warmed by a certain space of incandescent fire, and 1 square inch has been supposed sufficient to warm 8·4 cubic feet of air. But much depends on the walls, and whether the rays fall on them and warm them, and the air passing over them.

Radiating grates should be so disposed as that every ray is thrown out into the room. The rules indicated by Desaguliers were applied by Rumford. Count Rumford made the width of the back of the grate one-third the width of the hearth recess; the sides then sloped out to the front of the recess; the depth of the grate from before backwards was made equal to the width of the back. The sides and back were to be made of non-conducting material; the chimney throat was contracted so as to lessen the draught, and ensure more complete combustion. The grate was brought as far forward as possible,† but still under the throat.

The open chimney, which is a necessity of the use of radiant grates, is so great an advantage that this is *per se* a strong argument for the use of this kind of warming, but, in addition, there can be little doubt that radiant heat is really the healthiest.

Still in large rooms it is not sufficient, and must be supplemented by

Convection and Conduction.

The air is heated in this case by passing over hot stones, earthenware, iron, or copper plates, hot water or steam pipes. The air in the room is thus heated, or the air taken from outside is warmed, and is then allowed to pass into the room, if possible at or near the floor, so that it may properly mingle with the air already there. The heat of the warming surface should not be great, probably not more than 120° to 140° Fahr.; there should be a large surface feebly heated. The air also should not be heated above 75° or 80° Fahr., and a large body of air gently heated should be preferred to a smaller body heated to a greater extent, as more likely to mix thoroughly with the air of the room.

It does not matter what the kind of surface may be, provided it is not too

* My friend Dr Sankey has made experiments, which show that the temperature of the air of a room heated by radiant heat is really lower than the indicated temperature of the air, because the bulb is warmed by radiation. When this is prevented by enclosing the bulb in a bright tin case, the thermometer falls.

† It has been truly said that, in spite of the constant use of Count Rumford's name, not one grate in 10,000 is made according to his principles.

hot. If it is, the air acquires a peculiar smell, and is said to be burnt; this has been conjectured to be from the charring of the organic matter. Some have supposed the smell to be caused by the effect of the hot air on the mucous membrane of the nose, but it is not perceived in air heated by the sun. Such air is also relatively very dry, and absorbs water eagerly from all substances which can yield it.

If air is less heated (not more than 75°) it has no smell, and the relative humidity is not lessened to an appreciable extent. Haller's experiments, carried on over six years with the Meissner stove common in Germany, show that there the relative moisture is not lessened with moderate warming.* I have made experiments with the Galton stove used in barracks with the same result. On the other hand, when the plates are too hot, the air may be really too much dried, and Dr Sankey informs me that while he never found the difference between the dry and wet bulbs in a room warmed by radiant heat to be more than 8° Fahr., he has noticed in rooms warmed by hot air a difference of 15° to 17° Fahr., which implies a relative humidity, if the temperature be 60°, of only 34 per cent. of saturation, which is much too dry for health. In this case the air is always unpleasant, and must be moistened by passing over water before it enters the room, if possible; some heat is thus lost, but not much. Of the various means of heating, water is the best, as it is more under control; steam is equally good, if waste steam can be utilised, but if not, it is more expensive. Hot-water pipes are of two kinds: pipes in which the water is not heated above 200° Fahr., and which, therefore, are not subjected to great pressure; and pipes in which the water is heated to 300° or 350° Fahr., and which are therefore subjected to great pressure. These pipes (Perkins' patent) are of small internal calibre (about $\frac{1}{2}$ inch), with thick walls made of two pieces of welded iron; the ends of the pipes are joined by an ingeniously contrived screw. In the low-pressure pipes there is a boiler from which the water circulates through the pipes and returns again, outlets being provided at the highest points for the exit of the air. In Perkins' system there is no boiler; one portion of the tube passes through the fire.

The amount of tubing (low pressure) which must be given, requires a good deal of calculation; the following rule is given by Hood:—If the pipes be four inches diameter and the water be at 200°, then divide the cubic contents of the room by 200, and the quotient will be the number of feet of pipe in length to keep the room at 55° Fahr. when the external air is 32°. If Perkins' pipes are used, as the heating power is greater, a less amount does, probably about two-thirds, or a little more.

The easy storing up and conveyance of heat to any part of the room or house by means of water pipes, the moderate temperature, and the facility of admission of external air at any point by passing the fresh air over coils or water leaves, make it certain that the plan of warming by hot water will be universally used in time to come, although the open fire-place may be retained for comfort.

A plan which was proposed 130 years ago by Desaguliers is now coming into general use, viz., to have an air-chamber round the back and sides of a radiating grate, and to pass the external air through it into the room. Thus a great economy of heat, and a considerable quantity of gently-warmed air, passes into the room. The Meissner stove of Germany is a very ingenious stove of this sort, only there is no open fire. In Captain Galton's grate, and in the plan proposed by Mr Chadwick for cottages, the lower part of the

* Die Lüftung und Erwärmung der Kinderstube und des Krankenzimmers, von D. C. Haller, 1860, pp. 29–38.

chimney is also made use of. The advantages of these grates are that they combine a good amount of cheerful open fire, radiant heat, and chimney ventilation, with supplementary warming by hot air, so that more value is obtained from the fuel, and larger spaces can be more effectually warmed. A great number of patents have been taken out for grates of this kind. They have some defects; the air-chamber should not be too small, or the air is unduly heated; the heated surface should be very large; fire-clay sometimes gives a peculiar odour to the air, which iron does not do if the surface of iron be very large and disposed in gills; a combination also of fire and fire-clay is said to be good, and to give no odour. The conduit leading to the air-chamber should be short, and both it and the chamber should be able to be opened and cleaned, as much dust gets in. This is an important point. The room opening of the air-chamber should be so far up that the hot air may not be at once breathed, and there should be no chance of its being at once drawn up the chimney.

Attention has been lately directed both in France and America to the fact of the comparative ease with which gases pass through red-hot cast-iron. Mr Graham has shown that iron heated to redness will absorb 4·15 times its volume of carbonic oxide, and the experiments by MM. Deville and Troost, made at the request of General Morin, prove that in a cast-iron stove heated with common coal there passed through the metal in 92 hours 589 C.C. of carbonic oxide,* or from ·0141 to ·132 per cent. of the air which was slowly passed over the hot surface. In America, Dr Derby† has directed particular attention to this point, and has adduced very strong reasons for believing that the decidedly injurious effects produced by some of the plans of warming houses, especially by air passing over a east-iron furnace heated with anthracite, is due to this admixture of carbonic oxide. Professor Coulier of the Val de Grâce‡ has, however, contended that the amount of carbonie oxide passing through in the experiments of Deville and Troost is really so small, that if mixed with the air of a room which is fairly ventilated, it would be quite innocuous; and he believes (from direct experiment) that the headache and oppressive feeling produced by these iron stoves are really owing, as was formerly believed, to the relative dryness of the air. Dr Derby, however, has adduced some very strong arguments against such a view; and it seems really probable that the passing of carbonic oxide in this way is the cause of the peculiar effects which certainly arise from the use of these extremely hot cast-iron stoves. The gas passes with much greater difficulty through wrought-iron, or through stoves lined with fire-clay.

A great number of grates and stoves have been proposed, which it is impossible here to notice. The medical officers advice will be sought, first, as to the kind, and second, as to the amount of heat. He will find no difficulty in coming to the conclusion that in most cases both methods (radiation and convection) should be employed; the air warmed by plates or coils of water-pipes being taken fresh from the external air and thereby conducing to ventilation. He will be also called on to state the relative amount of radiant and convected heat, and to determine the heat of the plates, and of the air coming off them, and the degree of humidity of the air. The thermometer, and the dry and wet bulbs, will give him all the information he wants on these points.

* Comptes Rendus de l'Acad. Jan. 1868. These experiments were first undertaken in consequence of a statement by Dr Carret, that in the department of Haute-Savoie, an epidemic occurred which affected persons only in the houses where iron stones were, and not porcelain.

† Anthracite and Health, by G. Derby, M.D., Professor of Hygiène in Harward University.

‡ Mem. de Med. Mil., Sept. 1868, p. 250.

CHAPTER XIII.

EXERCISE AND PHYSICAL TRAINING.

A PERFECT state of health implies that every organ has its due share of exercise. If this is deficient, nutrition suffers, the organ lessens in size, and eventually more or less degenerates. If it be excessive, nutrition, at first apparently vigorous, becomes at last abnormal, and, in many cases, a degeneration occurs which is as complete as that which follows the disuse of an organ. Every organ has its special stimulus which excites its action, and if this stimulus is perfectly normal as to quality and quantity, perfect health is necessarily the result.

But the term exercise is usually employed in a narrower sense, and expresses merely the action of the voluntary muscles. This action, though not absolutely essential to the exercise of other organs, is yet highly important, and indeed, in the long run, is really necessary; the heart especially is evidently affected by the action of the voluntary muscles, and this may be said of all organs, with the exception perhaps of the brain. Not only the circulation of the blood, but its formation and its destruction, are profoundly influenced by the movement of the voluntary muscles. Without this muscular movement health must inevitably be lost, and it becomes therefore important to determine the effects of exercise, the amount which should be taken, and the consequences of deficiency or of excess.

SECTION I.

THE EFFECTS OF EXERCISE.

(*a.*) *On the Lungs—Elimination of Carbon.*—The most important effect of muscular exercise is produced on the lungs. The pulmonary circulation is greatly hurried, and the quantity of air inspired, and of carbonic acid expired, is marvellously increased. Dr Edward Smith has carefully investigated the first point, and the following table shows his main results. Taking the lying position as unity, the quantity of air inspired was found to be as follows:—

Lying position, . .	1	Walking and carrying 62 lb,	3·84
Sitting, . . .	1·18	,, ,, 118 lb,	4·75
Standing, . . .	1·33	,, 4 miles per hour,	5
Singing, . . .	1·26	,, 6 ,,	7
Walking 1 mile per hour,	1·9	Riding and trotting, .	4·05
,, 2 ,,	2·76	Swimming, . . .	4·33
,, 3 ,,	3·22	Treadmill, . . .	5·5
,, and carrying 34 lb,	3·5		

The great increase of air inspired is more clearly seen when it is put in this way: Under ordinary circumstances a man draws in 480 cubic inches per minute; if he walks four miles an hour he draws in (480 × 5 =) 2400 cubic inches; if 6 miles an hour (480 × 7 =) 3260 cubic inches. Simultaneously, the amount of carbonic acid in the expired air is increased (Scharling and many others).

The most reliable observations in this direction are those made by E. Smith, Hirn,* Speck,† and Pettenkofer and Voit.‡ As there is no doubt that the peculiar means of investigation render the experiments of the last named authors as accurate as possible in the present state of science, I give them briefly in the following table.§

Absorption and Elimination in Rest and Exercise.

	Absorption of Oxygen in Grammes.	Elimination in Grammes of—		
		Carbonic Acid.	Water.	Urea.
Rest-day, ...	708·9	911·5	828·0	37·2
Work-day, ...	954·5	1284·2	2042·1	37
Excess on work-day (with exception of urea), ...	246·6	372·7	1214·1	– 0·2

In other words, during the work-day, 3804 grains or 8·69 ounces of oxygen were absorbed in excess of the rest-day, and 5750 grains or 13 ounces in excess of carbonic acid were evolved. Expressing this as carbon, an excess of 1568 grains or 3·58 ounces were eliminated in the work-day. There was an excess of oxidation of carbon equal to 36·4 per cent., and it must be remembered that the so-called "work-day" included a period of rest; the work was done only during working hours, and was not excessive.

It will be observed from these experiments that a large amount of water was eliminated during exercise, while the urea was slightly lessened.

It seems certain that the great formation of carbonic acid takes place in the muscles;‖ it is rapidly carried off from them, and if it is not so, it would seem highly probable that their strong action becomes impossible. At any rate, if the pulmonary circulation and the elimination of carbonic acid are in any way impeded, the power of continuing the exertion rapidly lessens. The watery vapour exhaled from the lungs is also largely increased during exertion.

Muscular exercise is then clearly necessary for a sufficient elimination of carbon from the body, and it is plain that, in a state of prolonged rest, either the carboniferous food must be lessened or carbon will accumulate.

Excessive and badly arranged exertion may lead to congestion of the lungs and even hæmoptysis. Deficient exercise, on the other hand, is one of the causes which produce those nutritional alterations in the lung which we class as tuberculous.

Certain rules flow from these facts. During exercise the action of the lungs must be perfectly free; not the least impediment must be offered to the freest play of the chest and the action of the respiratory muscles. The dress and accoutrements of the soldier should be planned in reference to this fact, as there is no man who is called on to make, at certain times, greater exertion.

* Ludwig's Phys. 2d edit. band i. p. 743.

† Archiv des Verrins für wiss. Heilk. band vi. pp. 285 and 289.

‡ Zeitsch. für Biologie, band ii. and iii., and Ranke's Phys. des Menschen, p. 551.

§ The numbers given by Hirn and Speck are very accordant; they will be found quoted in the 2d edition of this work, if it is wished to refer to them.

‖ See the observations of Valentin and others, and especially the experiments of Sczelkow (Henle's Zeitschrift, 1863, band xvii. p. 106). The amount of CO_2 passing off from contracting muscles was indeed so great, and so much in excess of the O passing to them, that it was conjectured that carbonic acid must have been formed during contraction from substances rich in oxygen (such as formic acid), or that oxygen must have been obtained otherwise than from inspiration.

And yet, till a very recent date, the modern armies of Europe were dressed and accoutred in a fashion which took from the soldier, in a great degree, that power of exertion for which, and for which alone, he is selected and trained. The action of the lungs should be watched when men are being trained for exertion; as soon as the respirations become laborious, and especially if there be sighing, the lungs are becoming too congested, and rest is necessary.

A second point is, that the great increase of carbon excreted demands an increase of carbon to be given in the food. There seems a general accordance, among physiologists, that this is best given in the form of fat, and not of starch, and this is confirmed by the instinctive appetite of a man taking exertion, and not restrained in the choice of food.

A third rule is, that as spirits lessen the excretion of pulmonary carbonic acid, they are hurtful during exercise; and it is perhaps for this reason, as well as from their deadening action on the nerves of volition, that those who take spirits are incapable of great exertion. This is now well understood by trainers, who allow no spirits, and but little wine or beer. It is a curious fact, stated by Artmann, that if men undergoing exertion take spirits, they take less fat. Possibly in reality they lessen the amount of exertion, and therefore require less fat. Water alone is the best fluid to train on.

A fourth rule is, that as the excretion of carbonic acid (and perhaps of pulmonary organic matter) is so much increased, a much larger amount of pure air is necessary; and in every covered building (as gymnasia, riding-schools, &c.) where exercise is taken, the ventilation must be carried to the greatest possible extent, so soon does the air become vitiated.

(*b.*) *On the Heart and Vessels.*—The action of the heart rapidly increases in force and frequency, and the flow of blood through all parts of the body, including the heart itself, is augmented. The amount of increase is usually from ten to thirty beats, but occasionally much more. After exercise, the heart's action falls below its normal amount; and if the exercise has been exceedingly prolonged and severe, may fall as low as fifty or forty per minute, and become intermittent. During exertion, when the heart is not oppressed, its beats, though rapid and forcible, are regular and equable; but when it becomes embarrassed, the pulse becomes very quick, small, and then unequal, and even at last irregular. In examining men who are training for severe exercises, and especially in the case of young recruits, the heart's action must be carefully examined, and exercise should be at once discontinued for a time, if the strokes become extremely quick (120–140) and unequal. When men have gone through a good deal of exertion, and then are called upon to make a sudden effort, I have known the pulse become very small and quick (160–170), but still retain its equability. There seems no harm in this, but such exertion cannot be long continued.

The ascension of heights greatly tries a fatigued heart. The accommodation of the heart to great exertion is probably connected with the easy flow of blood through its own structure.

Excessive exercise leads to affection of the heart; rupture (in some few cases), palpitation, hypertrophy in a good many cases, and more rarely valvular disease. These may be avoided by careful training, and a due proportion of rest. Injuries to vessels may also result from too sudden or prolonged exertion. The sphygmographic observations of Dr Fraser* on the pulses of men after rowing show how much the pressure is increased.

Deficient exercise leads to weakening of the heart's action, and probably to dilatation and fatty degeneration.

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* Journal of Physiology, Nov. 1868.

In commencing an unaccustomed exercise, the heart must be closely watched; excessive rapidity (120–140), inequality, and then irregularity, will point out that rest, and then more gradual exercise, is necessary, in order that the heart may be accustomed to the work.

(*c.*) *On the Skin.*—The skin becomes red from turgescence of the vessels, and perspiration is increased; water, chloride of sodium, and acids (probably in part fatty), pass off in great abundance. It was formerly supposed that urea also passed off in this way, but this is not the case. No nitrogen is given off in healthy men from the skin.

The amount of fluid passing off is not certain, but is very great. Speck's experiments show that it is at least doubled under ordinary conditions. Pettenkofer and Voit's experiments show even a larger increase. The usual ratio of the urine to the lung and skin excreta is reversed. Instead of being 1 to 0·5 or 0·8, it becomes 1 to 1·7 or 2, or even 2·5. This evaporation reduces and regulates the heat of the body, which would otherwise soon become excessive; so that, as long ago pointed out by Dr John Davy, the body temperature rises little above the ordinary temperature. No amount of external cold seems to be able to hinder the passage of fluid, though it may partly check the rapidity of evaporation. If anything check evaporation, the body-heat increases, and soon languor comes on and exertion becomes difficult. It seems likely that to some check in evaporation, combined with interference with free pulmonary action, one form of the so-called heat-apoplexy is owing.

During exertion there is little danger of chill under almost any circumstances; but when exertion is over, there is then great danger of chill, because the heat of the body rapidly declines, and falls below the natural amount, and yet evaporation from the skin, which still more reduces the heat, continues.

The rules to be drawn from these facts are—that the skin should be kept extremely clean; during the period of exertion it may be thinly clothed, but immediately afterwards, or in the intervals of exertion, it should be covered sufficiently well to prevent the least feeling of coolness of the surface. Flannel is best for this purpose.

(*d.*) *On the Voluntary Muscles.*—The muscles grow, become harder, and respond more readily to volition. Their growth, however, has a limit; and a single muscle, or group of muscles, if exercised to too great an extent, will, after growing to a great size, commence to waste. But this seems not to be the case when all the muscles of the body are exercised, probably because no muscle can then be over-exercised. It seems to be a fact, however, that prolonged exertion, without sufficient rest, damages to a certain extent the nutrition of the muscles, and they become soft.

The rules to be drawn from these facts are, that all muscles, and not single groups, should be brought into play, and that periods of exercise must be alternated, especially in early training, with long intervals of rest.

(*e.*) *On the Nervous System.*—The effect of exercise on the mind is not clear. It has been supposed that intellect is less active in men who take excessive exercise, owing to the greater expenditure of nervous force in that direction. But there is no doubt that great bodily is quite consistent with extreme mental activity; and, indeed, considering that perfect nutrition is not possible except with bodily activity, we should infer that sufficient exercise would be necessary for the perfect performance of mental work. Doubtless, exercise may be pushed to such an extreme as to leave no time for mental cultivation; and this is perhaps the explanation of the proverbial stupidity of the athletæ. Deficient exercise causes a heightened sensitiveness of the nervous system, a sort of morbid excitability, and a greater susceptibility to the action of external agencies.

(*f.*) *On the Digestive System.*—The appetite largely increases with exercise, especially for meat and fat, but in a less degree, it would appear, for the carbo-hydrates. Digestion is more perfect, and absorption is more rapid. The circulation through the liver increases, and the abdominal circulation is carried on with more vigour. Food must be increased, especially nitrogenous substances, fats, and salts, and of these especially the phosphates and the chlorides.* The effects of exercise on digestion are greatly increased if it be taken in the free air, and it is then a most valuable remedy for some forms of dyspepsia (James Blake, *Pacific Medical and Surgical Journal*, 1860). Conversely, deficient exercise lessens both appetite and digestive power.

(*g.*) *On the Generative Organs.*—It has been supposed that puberty is delayed by physical exertion, but perhaps the other circumstances have not been allowed full weight. Yet, it would appear that very strong exercise lessens sexual desire, possibly because nervous energy is turned in a special direction.

(*h.*) *On the Kidneys.*—The water of the urine and the chloride of sodium often lessen in consequence of the increased passage from the skin. The urea is not much changed (see after). The uric acid increases after great exertion; so also apparently the pigment; the phosphoric acid is not augmented;† the sulphuric acid is moderately increased; the free carbonic acid of the urine is increased; the chlorides are lessened on account of the outflow by the skin; the exact amount of the bases has not been determined, but a greater excess of soda and potash is eliminated than of lime or magnesia; nothing certain is known as to hippuric acid, sugar, or other substances.

(*i.*) *On the Bowels.*—The effect of exercise is to lessen the amount, partly, probably, from lessened passage of water into the intestines. The nitrogen does not appear to be much altered.‡

On the Elimination of Nitrogen.—A great number of experiments have been made in the amount of nitrogen passing off by the kidneys during exercise.§ The amount of urea has been usually determined, and the nitrogen has been calculated from this; Meissner has determined the amount of the creatin, and the creatinine;|| while Fick, and Wislicenus have compared the total nitrogen (by soda lime in the manner of Voit) as well the ureal nitrogen, and I have repeated their experiments.¶ The experiments have been usually carried on by determining the nitrogenous excretion in twenty-four hours with and without exercise; but in some, the period during which work was actually performed was compared with previous and subsequent equal rest periods. Some experiments were performed on men who took no nitrogen as food; others were on men on a constant diet, so that the variation produced by the altering ingress of nitrogen was avoided as far as possible.

In this place it is impossible to give an account of these long researches, and I must venture on a short summary. (*a.*) When a period of exercise is

* It is yet uncertain what kind of diet should be allowed during long marches in the tropics. Dr Kirk has informed me that in South Africa (10° to 17° S.L.), during Dr Livingston's second expedition, a large quantity (2 ℔) of animal food was found to be essential; this was preferred, though any quantity of millets and leguminosæ could have been procured. Fat was taken in large quantity. It was found, also, that boiled was better than roast meat, because the men could eat more of it. No bad effect whatever was traceable to the use of this great amount of meat, even in the intensest heat.

† I believe I can be certain of this from my own experiments.

‡ Proceedings of Royal Society, No. 94, 1867, p. 52.

§ For a statement of these experiments up to 1860, I may refer to my work "On the Composition of the Urine," 1860, p. 85. Since this time the chief experiments have been by Voit, Pettenkofer, J. Ranke, E. Smith, Haughton, Fick and Wislicenus, Byasson, Noyes, Meissner, and others.

|| Henle's Zeitschift für rat. Med. band xxxii. p. 283.

¶ Proceedings of the Royal Society, No. 89 (1867), and No. 94 (1867).

compared after an interval with one of rest (the diet being without nitrogen or with uniform nitrogen), the elimination of nitrogen by the kidneys is decidedly not increased in the exercise period. The experiments on this point are now so numerous that it may be stated without doubt. It is possible that the elimination may even be less during the exercise than during the work period. This would appear in part from some of Ranke's, and Fick and Wislicenus' experiments; from Noyes, as far as regards the urea; and from Meissner's, as far as the creatin (or creatinine) is concerned; while I found a decrease both in the total nitrogen and in the urea. The decrease in my experiments was not inconsiderable. Additional observations are, however, much wanted on this point.

(*b.*) When a day of rest is compared with a day of work (*i. e.*, a day with some hours of work and some hours of rest), the amount of nitrogen is almost or quite the same on the two days; if anything there is a slight increase in the nitrogen on the rest day. In a day of part exercise and part rest, it is quite possible that there may be compensatory action, one part balancing the other, so as to leave the total excretion little changed.

(*c.*) When a period of great exercise is immediately followed by an equal period of rest, the nitrogenous elimination is increased in the latter. Meissner's observations show that this is in part owing to increased discharge of creatin and creatinine; my observations also show an increase of non-ureal nitrogen. But the urea is also slightly increased in this period.

(*d.*) When two days of complete rest are immediately followed by days of common exercise, the nitrogenous elimination diminishes during the first day of exercise.*

On the whole, if I have stated the facts correctly, the effect of exercise is certainly to influence the elimination of nitrogen by the kidneys, but within narrow limits, and the time of increase is in the period of rest succeeding the exercise; while during the exercise period the evidence, though not certain, points rather to a lessening of the elimination of nitrogen.

It would appear from these facts that well-fed persons taking exercise would require a little more nitrogen in the food, and it is certain, as a matter of experience, that persons undergoing laborious work do take more nitrogenous food. This is the case also with animals. The possible reason of this will appear presently.

Changes in the Muscles.—The discussion on this head involves so many obscure physiological points, that it would be out of place to pursue it here to any length. The chief changes during action appear to be these :—There is a considerable increase in temperature (Helmholtz) which, up to a certain point, is proportioned to the amount of work. It is also proportioned to the kind, being less when the muscle is allowed to shorten than if prevented from shortening (Heidenhain); the neutral or alkaline reaction of the tranquil muscle becomes acid from para-lactic acid and acid potassium phosphate; the venous blood passing from the muscles becomes much darker in colour, is much less rich in oxygen, and contains much more carbonic acid (Sczelkow); the extractive matters soluble in water lessen, those soluble in alcohol increase (Helmholtz, in frogs); the amount of water increases (in tetanus, J. Ranke), and the blood is consequently poorer in water; the amount of albumen in tetanus is less according to Ranke, but Kühne has pointed out that the numbers do not justify this inference.† Baron J. von Liebig stated that

* This fact at present rests only upon my observations; it has an important bearing on the interpretation of the facts connected with the elimination of nitrogen, and I hope observations by others will soon confirm or disprove it.

† Lehrb. der phys. Chem. 1868, p. 323.

the creatin is increased (but this was an inference from old observations on the extractum carnis of hunted animals, and requires confirmation). Sarokin has stated the same fact in respect of the frog. The electro-motor currents show a decided diminution during contraction.

That great molecular changes go on in the contracting muscles is certain, but their exact nature is not clear; according to Ludimar Hermann,* there is a jelly-like separation and coagulation of the myosin, and then a resumption of its prior form, so that there is a continual splitting of the muscular structure into a myosin coagulum, carbonic acid, and a free acid, and this constitutes the main molecular movement. But no direct evidence has been given of this.

The increased heat, the great amount of carbonic acid, and the disappearance of oxygen, combined with the respiratory phenomena already noted, all seem to show that an active oxidation goes on, and it is very probable that this is the source of the muscular action. The oxidation may be conceived to take place in two ways—either during rest oxygen is absorbed and stored up in the muscles and gradually acts there, producing a substance which, when the muscle contracts, splits up into lactic acid, carbonic acid, &c.; or, on the other hand, during the contraction an increased absorption of oxygen goes on in the blood and acts upon the muscles, or on the substances in the blood circulating through the muscles.† The first view is strengthened by some of Pettenkofer and Voit's experiments, which show that during rest a certain amount of storage of oxygen goes on, which is no doubt in part stored in the muscles themselves. Indeed, it has been inferred that it is this stored up oxygen, and not that breathed in at the time, which is used in muscular action. The increased oxidation gives us a reason why the nitrogenous food must be increased during periods of great exertion. An increase in the supply of oxygen is a necessity for increased muscular action; but Pettenkofer and Voit's observations (see page 159), have shown that the absorption of oxygen is dependent on the amount of the nitrogenous structures of the body, so that, as a matter of course, if more oxygen is required for increased muscular work, more nitrogenous food is necessary. But apart from this, although experiments on the amount of nitrogenous elimination show no very great change on the whole, there is no doubt that, with constant regular exercise, a muscle enlarges, becomes thicker, heavier, contains more solid matter, and in fact has gained in nitrogen. This process may be slow, but it is certain; and the nitrogen must either be supplied by increased food, or be taken from other parts.‡

So that although we do not know the exact changes going on in the muscles, it is, I presume, certain that regular exercise produces in them an addition of nitrogenous tissue.

Whether this addition occurs, as usually believed, in the period of rest succeeding action, when in some unexplained way the destruction which it is presumed has taken place, is not only repaired, but is exceeded (a process difficult to understand), or whether the addition of nitrogen is actually made during the action of the muscle,§ must be left undecided for the present.

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* Unters. über den Stoffwechsel der Muskeln, von Dr L. Hermann; Weitere Untersuch. zur phys. der Muskeln, von Dr L. Hermann, 1867.

† Heaton (Quarterly Journal of Science, 1868), has given strong reasons for believing that the oxidation goes on in the blood.

‡ The way in which a vigorously acting part will rob the body of nitrogen, and thus, in some cases cause death, is seen in many cases of disease. A rapidly growing cancer of the liver, for example, takes so much nitrogen as well as fat that it actually starves the rest of the body, and both voluntary muscles and heart waste. This is the case, though it is less marked, with growing tumours of other parts, and with great discharges. Powerful muscular action, if the food is not increased, evidently acts in something the same way; the health is greatly affected, and the heart especially fails.

§ I have suggested, in a paper in the "Proceedings of the Royal Society," No. 94, 1867, this

The substances which are thus oxidised in the muscle, or in the blood circulating through it, and from which the energy manifested, as heat or muscular movement, is believed to be derived, may probably be of different kinds. Under ordinary circumstances the experiments and calculations of Fick and Wislicenus, and others, and the arguments of Traube, seem sufficient to show that the non-nitrogenous substances, and perhaps especially the fats, furnish the chief substances acted upon. But it is by no means improbable that the nitrogenous substances also furnish a contingent of force, though this, under ordinary circumstances, is small. The exact mode in which the energy thus liberated by oxidation is made to assume the form of mechanical motion is quite obscure.

The Exhaustion of Muscles.

There seems little doubt that the exhaustion of muscles is chiefly owing to two causes—first, and principally, to the accumulation in them of the products of their own action (especially para-lactic acid); and, secondly, from the exhaustion of the supply of oxygen. Hence rest is necessary, in order that the blood may neutralise and carry away the products of action, so that the muscle may recover its neutrality and its normal electrical currents, and may again acquire oxygen in sufficient quantity for the next contraction. In the case of all muscles these intervals of action and of exhaustion take place, in part even in the period which is called exercise, but the rest is not sufficient entirely to restore it. In the case of the heart, the rest between the contractions (about two-thirds of the time), is sufficient to allow the muscle to perfectly recover itself.

The body after exertion eagerly absorbs and retains water; the water, though taken in large quantities, does not pass off as rapidly as usual by the kidneys or the skin, and instead of causing an augmented metamorphosis, as it does in a state of rest, it produces no effect whatever. So completely is it retained, that, although the skin has ceased to perspire, the urine does not increase in quantity for several hours. The quantity of water taken is sometimes so great as not only to cover the loss of weight caused by the exercise, but even to increase the weight of the body.

We can be certain, then, of the absolute necessity of water during and after exercise, and the old rule of the trainer, who lessened the quantity of water to the lowest point which could be borne, must be wrong. In fact, it is now being abandoned by the best trainers, who allow a liberal allowance of fluid. The error probably arose in this way: if, during great exertion, water is denied, at the end of the time an enormous quantity is often drunk, more, in fact, than is necessary, in order to still the overpowering thirst. The sweating which the trainer had so sedulously encouraged is thus at once compensated, and, in this view, all has to be done over again. All this seems to be a misapprehension of the facts. The body must have water, and the proper plan is to let it pass in small quantities and frequently; not to deny it for hours, and then to allow it to pass in in a deluge. The plan of giving it in small quantities frequently, does away with two dangers, viz., the rapid passage of a large quantity of cold water into the stomach and blood, and the taking more than is necessary.*

view, which seems to me not only in accordance with the facts of the nitrogenous elimination as far as known, but to agree with Pettenkofer and Voit's experiments on the storing up of the oxygen and its probable action during rest. But I do not think it is desirable, until many more experiments have been made, to accept this view in any other light than an hypothesis. If it be correct, it will have important consequences on the doctrine of nutrition, but it would be premature to use it at present to explain the phenomena of growth and decay.

* It is but right to say that many travellers of great experience have expressed great fear

In the French army, on the march, the men are directed not to drink; but if very thirsty, to hold water in the mouth, or to carry a bullet in the mouth. It is singular, in that nation of practical soldiers, to find such an order. Soldiers ought to be abundantly supplied with water, and taught to take small quantities, when they begin to feel thirsty or fatigued. If they are hot, the cold water may be held in the mouth a minute or two before swallowing, as a precaution; though, I must say, as far as I have seen, I have never known any ill effects from drinking a moderate quantity of cold water, even during the greatest heat of the body.*

General Effect of Exercise on the Body, as judged of by the preceding facts.—The main effect of exercise is to increase oxidation of carbon, and perhaps also of hydrogen; it also eliminates water from the body, and this action continues, as seen from Pettenkofer and Voit's experiments, for some time; after exercise, the body is therefore poorer in water, especially the blood; it increases the rapidity of circulation everywhere, as well as the pressure on the vessels, and therefore it causes in all organs a more rapid outflow of plasma and absorption; in other words, a quicker renewal. In this way also it removes the products of their action, which accumulate in organs; and restores the power of action to the various parts of the body. It increases the outflow of warmth from the body by increasing perspiration. It therefore strengthens all parts. It must be combined with increased supply both of nitrogen and carbon (the latter possibly in the form of fat), otherwise the absorption of oxygen, the molecular changes in the nitrogenous tissues, and the elimination of carbon, cannot go on. There must be also an increased supply of salts, certainly of chloride of sodium; probably of potassium phosphate and chloride. There must be proper intervals of rest, or the store of oxygen, and of the material in the muscles which is to be metamorphosed during contraction, cannot take place. The integrity and perfect freedom of action both of the lungs and heart is essential, otherwise neither absorption of oxygen nor elimination of carbon can go on, nor can the necessary increased supply of blood be supplied to the acting muscles without injury.

In all these points, the inferences deducible from the physiological inquiries seem to be quite in harmony with the teachings of experience.

SECTION II.

AMOUNT OF EXERCISE WHICH SHOULD BE TAKEN.

It would be extremely important to determine, if possible, the exact amount of exercise which a healthy adult, man or woman, should take. Every one knows that great errors are committed, chiefly on the side of defective exercise. It is not, however, easy to fix the amount even for an average man, much less to give any rule which shall apply to all the divers conditions of health and strength.

The external work which can be done by a man daily has been estimated at $\frac{1}{7}$th of the work of the horse; but if the work of a horse is considered to be equal to the 1-horse power of a steam engine (viz. 33,000 ℔ raised 1 foot high per

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of water under exertion. Some of them have most strongly urged that "water be avoided like poison," and have stated that a large quantity of butter is the best preventive of thirst. At any rate, the butter may be excellent, but a little water is a necessity.

* Horses also used to be, and by some are now, deprived or stinted of water during exercise. But in India, the native horsemen give their horses drink as often as they can; and Dr Nicholson tells me this is the case with the Cape horses; even when the horses are sweating profusely, the men will ride them into a river, bathe their sides, and allow them to drink.

minute, or 8839 tons raised 1 foot high in ten hours), this must be an over-estimate, as $\frac{1}{7}$th of this would be 1265 tons raised 1 foot in a day's work of ten hours.* The hardest day's work of twelve hours I have ever myself known a man do, was in the case of a workman in a copper rolling-mill. He stated that he occasionally raised a weight of 90 ℔ to a height of 18 inches, 12,000 times a-day. Supposing this to be correct, he would raise 723 tons 1 foot high. But this much overpasses the usual amount. The same man's ordinary day's work, which he considered extremely hard, was raising a weight of 124 ℔ 16 inches, 5000 or 6000 times in a-day. Adopting the larger number, this would make his work equivalent to 442·8 tons lifted a foot; and this was a hard day's work for a powerful man. Some of the puddlers in the iron country, and the glass-blowers, probably work harder than this; but I am not aware of any calculations. I learn from a pedlar, that an ordinary day's work was to carry 28 ℔ twenty miles daily. The weight is balanced over the shoulder; 14 ℔ behind and 14 ℔ in front. The work is equal to 419·5 tons lifted 1 foot. It would seem certain, that an amount of work equal to 500 tons lifted a foot is an extremely hard day's work, which perhaps few men could continue to do. 400 tons lifted a foot, is a hard day's work; and 300 tons lifted a foot, is an average day's work for a healthy, strong adult.†

The external work is thus 300 to 500 tons on an average; the internal work of the heart, muscles of respiration, digestion, &c., has been variously estimated; the estimates for the heart alone vary from 122 to 277 tons lifted a foot. The former is that given by Haughton, who estimates the respiratory movements as about 11 tons lifted a foot in 24 hours. Adopting a mean number of 260 tons for all the internal mechanical work, and the external

* In some works on physiology a man's work of eight hours has been put as high as 316,800 kilogrammemetres, or 1020 tons lifted a foot; but this is far too much.

† In this country, the amount of work done is generally estimated as so many ℔s. or tons lifted 1 foot. In France it is expressed as so many kilogrammes lifted 1 metre. Kilogramme-metres are converted into foot-pounds, by multiplying by 7·216. To bring at once into tons lifted a foot, multiply by ·003221. The following table may be useful, as expressing amount of work done. It is taken from Mr Haughton's work ("A New Theory of Muscular Action"). The numbers are a little different from those given by Coulomb, as they have been recalculated by Mr Haughton, 1863.

LABOURING FORCE OF MAN.

Kind of Work.	Amount of Work.	Authority.
Pile driving,	312 tons lifted 1 foot.	Coulomb.
Pile driving,	352 ,, ,,	Lamande.
Turning a winch,	374 ,, ,,	Coulomb.
Porters carrying goods, and returning unladen,	325 ,, ,,	,,
Pedlars always loaded,	303 ,, ,,	,,
Porters carrying wood up a stair, and returning unloaded,	381 ,, ,,	,,
Paviours at work,	352 ,, ,,	Haughton.
Military prisoners at shot drill (3 hours), and oakum picking, and drill,	310 ,, ,,	,,
Shot drill alone (3 hours),	160·7 ,, ,,	,,

It may be interesting to give some examples of work done in India by natives, which have been given me by Dr de Chaumont:—

A Leptcha hill-coolie will go from Punkabarree to Darjeeling (thirty miles, and an ascent of 5500 feet), in three days, carrying 80 ℔ weight. The weight is carried on a frame supported on the loins and sacrum, and aided by a band passed round the forehead.

Work per diem, 500 tons lifted 1 foot.

Eight palanquin bearers carried an officer weighing 180 ℔, and palanquin weighing 250 ℔, twenty-five miles, in Lower Bengal. Assuming each man weighed 150 ℔, the work was 600 tons lifted a foot.

work of a mechanic being 300 to 500 tons, this will amount to from $\frac{1}{7}$th to $\frac{1}{6}$th of all the force obtainable from the food of the soldier.

The exertion which the infantry soldier is called upon to undergo is chiefly drill, and carrying weights on a level, or over an uneven surface.

The Reverend Professor Haughton, M.D., who is so well known for his important contributions to physiology and medicine, has shown that walking on a level surface is equivalent to raising $\frac{1}{20}$th part of the weight of the body, through the distance walked; an easy calculation changes this into the weight raised 1 foot. When ascending a height, a man of course raises his whole weight through the height ascended.

Using this formula,* and assuming the soldier to weigh 150 lb with his clothes, we get the following table:—

Kind of Exercise.	Work done in Tons lifted 1 foot.
Walking 1 mile,	17·67
„ 2 „	35·34
„ 10 „	176·7
„ 20 „	353·4
„ 1 „ and carrying 60 lb,	24·75
„ 2 „ „	49·5
„ 10 „ „	247·5
„ 20 „ „	495

It is thus seen that a march of ten miles, with a weight of 60 lb (which is nearly the weight a soldier carries when in marching order, but without blankets and rations), is a moderate day's work. A twenty-miles march, with 60 lb weight, is a very hard day's work. As a continued labouring effort, Mr Haughton believes that walking twenty miles a-day, without a load (Sunday being rest), is good work (353 tons lifted a foot); so that the load of 60 lb additional would make the work too hard for a continuance.

It must, however, be remembered, that it is understood that the walking is on level ground, and is done in the easiest manner to the person, and that the weights which are carried are properly disposed. The labour is greatly increased if the walk is irksome, and the weights are not well adjusted. And this is the case with the soldier. In marching, his attitude is stiff; he observes a certain time and distance in each step; he has none of those shorter and longer steps, and slower and more rapid motion, which assist the ordinary pedestrian. The weights he carries are also (as will be hereafter noticed) so badly disposed, as to add greatly to the labour. It may be questioned, indeed, whether the formula does not under-estimate the amount of work actually done by the soldier. The work becomes heavier, too, *i.e.*, more exhausting, if it is done in a shorter time; or, in other words, velocity is gained at the expense of carrying power. The velocity in fact, *i.e.*, the rate at which work is done, is an important element in the question, in consequence of the strain thrown on the heart and lungs. The Oxford boat races —rowing at racing speed (= 1 mile in 7 minutes) in an Oxford eight-oar, or 18·56 foot-tons in 7 minutes† is not apparently very hard work, but it is very severe for the time, as its effect is great on the circulatory system.

Ordinary drill, without arms, is regarded by Mr Haughton to be equivalent

* The formula is $\frac{(W + W') \times D}{20 \times 2240}$; where W is the weight of the person, W′ the weight carried; D the distance walked in feet; 20 the co-efficient of traction; and 2240 the number of pounds in a ton. The result is the number of tons raised 1 foot. To get the distance in feet, multiply 5280 by the number of miles walked.

† Training, by A. Maclaren, p. 168.

to walking; but considering the constrained attitudes, and the tension of particular muscles, it seems but right to reckon it one-third more severe than common walking.

In addition to drill and marching, the soldier has to perform other duties, such as cleaning arms and rooms, &c., of which the exact amount of work cannot be calculated. On the whole, in ordinary times during peace, the work done by the soldier is certainly not excessive, on some days is even slight.

The shot-drill which military prisoners perform under certain circumstances is carried on for three hours daily. A man stoops down and lifts a 32 ℔ shot from a low bench, erects himself, steps 9 feet, and lowers the shot to another bench; he then returns empty-handed to the first bench, lifts another shot, carries it to the second bench, and so on. Six double journeys are performed per minute. He therefore walks 18 feet 360 times per hour, or 6480 feet per hour, carrying his own weight, and also, for half the distance, a shot of 32 ℔. He also lifts and puts down the weight of 32 ℔ twelve times per minute a height of 3 feet, or 2160 feet per hour. Assuming his weight to be 141 ℔, we find by the formula that the work is equal to 160·7 tons raised 1 foot.*

Looking at all these results, and considering that the most healthy life is that of a man engaged in manual labour in the free air, and that the daily work will probably average from 250 to 350 tons lifted 1 foot, we can perhaps say, as an approximation, that every healthy man ought, if possible, to take a daily amount of exercise in some way which shall not be less than 150 tons lifted one foot. This amount is equivalent to a walk of about 9 miles; but then, as there is much exertion taken in the ordinary business of life, this amount may be in many cases reduced. It is not possible to lay down rules to meet all cases, but probably every man with the above facts before him could fix the amount necessary for himself with tolerable accuracy.

In the case of the soldier, if he were allowed to march easily, and if the weights were not oppressively arranged, he ought to do easily 12 miles daily for a long time, provided he was allowed a periodical rest. But he could not for many days, without great fatigue, march 20 miles a-day with a 60 ℔ load, unless he were in good condition and well fed. If a greater amount still is demanded from him, he must have long subsequent rest. But all the long marches by our own or other armies have been made without weights, except arms and a portion of ammunition. Then great distances have been traversed by men in good training and condition.

SECTION III.

TRAINING.

As the trade of the soldier is, *par excellence*, an athletic one, and as he ought to be able and in readiness for any call on his energies, it is desirable

* The formula is

$$\left.\begin{array}{r}\text{Work in tons in shot-}\\ \text{drill for 180 minutes,}\end{array}\right\} = \left(\frac{(2\,W + 32)\,a}{20 \times 2240} + \frac{32 \times 2h}{2240}\right) \times n \times 180^{m}$$

Where W is the weight of the man,
a the distance the 32 ℔ shot is carried.
h the height in feet to which the shot is lifted.
n number double journeys per minute.

Substituting the values, we have

$$\text{work in tons} = \left(\frac{282\text{ ℔} + 32\text{ ℔}\,(\times 9\text{ feet})}{20 \times 2240} + \frac{32\text{ ℔} \times 6\text{ feet}}{2240}\right) \times 6\text{ journeys} \times 180\text{ minutes.}$$ —*Haughton.*

to say a few words on the system by which it is attempted to prepare men for great exertions.

The system of training is now conducted on much sounder principles than formerly. The old trainers, in addition to fanciful systems of diet, and, in some cases, the use of spirits, gave much purgative and diaphoretic medicine; so that digestion was weakened, and many men came out of their hands in really worse condition than they went in. Even now the system of training is so far faulty that men cannot be kept in high training for any length of time. Some of the best pedestrians now never go into training at all, but lead a life which keeps them always ready for their vocation. As far as I can learn, this life is a simple and sensible one. Plain and regular diet, without restriction to one set food; temperance; systematic exercise, not pushed to great excess; the avoidance of tobacco, or its use in great moderation; and great cleanliness, seem to be the chief points.

The rules now laid down by the best trainers are these. Their motto is now "Work and diet."

The diet is largely of lean meat. Underdone meat is still used, though there is no physiological reason for this. All that is wanted is that the meat should be perfectly digestible. Fat is excluded by most, and sugar also, or is given in small quantity; weak beer, or weak wine and water (two glasses of wine daily—sherry for pedestrians, port for boxers, but this is a mere fancy); but no spirits are used, and often nothing but water or barley-water is allowed. Tea and coffee are sometimes excluded. Tobacco is excluded by most. The man sleeps in a cool room, with free ventilation, and in beds not too hot; feather-beds are considered relaxing. Great cleanliness and the frequent use of the bath are rigorously enforced. Purgative physic is now never given, but sweating is produced by the feather-bed and blankets, by the Turkish bath, or by exercise in flannel. In the first case, during sweating, no water is given, and it is said the thirst goes when the sweating is over; but it seems as if the feather-bed sweating is now going out of fashion, or is only used once or twice when the men are very fat. The Turkish bath is regarded differently by different trainers—some use it; others call it detrimental. Sweating by exercise is the common plan, and little water is allowed.

The amount of work done is moderate at first, but is gradually increased, until a *régime* like the following is reached:—The man rises at an early hour; uses the dumb-bells or the chest-expander for some time, varying according to the period of training; then takes a cold bath, and starts for a walk of an hour, taking before starting a stale crust of bread, and perhaps a raw egg and a cup of infusion of gentian. He then breakfasts on meat and bread, with perhaps tea, but little or no sugar. An hour after breakfast he begins his exercises with dumb-bells or weights, or walks, according to his vocation, and is made to sweat profusely. The exercises vary in length according to the condition of the man and the time of training: they are at first light, and increase in severity. When training is at its height, about eight or ten hours are occupied in sleep, four in meals and rest, and the remaining ten or twelve in exercises more or less severe, or in quick walking. Training usually lasts six weeks.

The system is irksome, and prize-fighters sometimes find the training worse than the punishment they receive in the ring.

The result of this training is apparently greatly to improve the health. The skin gets clear, the eye bright, the temper cheerful; the movements of the body are easy and rapid; the breathing power of the lungs greatly augments; the urine is concentrated, and has in some cases a strong odour, which arises perhaps from the large amount of meat taken; there is little fat on the

body; the muscles are firm and resistent, so that they are not so easily bruised as usual, and injuries are sooner recovered from.

The fault of the system is to be found in the fanciful notions of diet which still prevail. The exclusion of fat and of the starches must reduce too much the amount of fat in the body, and must seriously interfere with the nutritiou of muscle. The true way of lessening fat is to be found in exercise, combined with such a lessening of the carboniferous food as may permit little or none to be stored up. Owing, probably, to this dietary, it appears to be true that many men are "overtrained," *i.e.*, too fine-drawn from absorption of fat, and few men can remain in high training for any length of time. Some of the best trainers now endeavour not to lessen the external fat too much; in fact, the criterion should be the breathing power, and muscular strength and rapidity, not the appearance of the man. That the deprivation of fat is an entire mistake, is not only a matter of reasoning, it is practically the case that men who take much exertion always take much fat. Before any great exertion there should be a period of rest, to enable the store of oxygen and material to be formed; and if the body has been previously well fed with nitrogen, a diet with fat and starches is the best just before the exertion.

After training, the men often compensate for their previous abstinence by great excesses, and pass from extreme work to a state of perfect idleness; and this is no doubt the principal cause that professional pedestrians and prize-fighters are not very healthy as a class. The same fact occurred among the athletes of Greece; as a class they were short-lived. Men of the better classes, training for boat-racing or other athletic sports, injure themselves by excessive exertion commenced too early in the training, and do not give time for the lungs to expand and the muscles to develop.

In the case of the soldier, he ought to be always in a state of training, if we use this term to express those habits which are best calculated to develop and maintain muscular vigour. In many respects, and especially in the cavalry branch of the service, where the care of the horses calls into play many muscles which in the infantry soldier are less used, the life of the soldier is a good one for muscular training. He has regular work, with proper intervals of rest, and, to a certain extent, good and well-cooked food. But it fails in the following points: In the infantry the attitudes are too stiff, and all the muscles are not equally exercised; the clothes are too tight, and the weights were till lately badly carried, and oppressed the lungs and heart. A great improvement was introduced by Lord de Grey, who advised that all men in the infantry under ten years' service should go through a three months' course of gymnastic training in the year (spreading over six months by taking every other day). If the food could be increased in quantity, especially in its nitrogenous and fatty constituents, the clothes loosened, and the weights properly carried, there would be no doubt that the soldier could be kept in a condition of perfect training; at least there would be only his own vices—drinking, excessive tobacco-smoking, and inordinate sexual indulgence—which could prevent this.

SECTION IV.

GYMNASTIC EXERCISES.

All military nations have used in their armies a system of athletic exercises. The Greeks commenced such exercises when the increase of cities had given rise to a certain amount of sedentary life. The Romans began to use athletic training in the early days of the Republic, entirely with a view to military

efficiency. The exercises were continuous, and were not alternated with periods of complete idleness.

The officers exercised with the men. At a later day we are told that Marius never missed a single day at the Campus Martius; and Pompey is said by Sallust to have been able at fifty-eight years of age to run, jump, and carry a load as well as the most robust soldier in his army.

Swimming was especially taught by the Romans, and so essential were the gymnastic exercises deemed that, to express that a man was completely ignorant, it was said "he knew neither how to read nor swim." The gymnastic exercises were the last of the old customs which disappeared before the increasing luxury of the later empire.

In the feudal times the practice of the weapons was the best gymnastic exercise; every peasant in England was obliged to practise with the bow; the noblemen underwent an enormous amount of exercise both with and without arms, and on foot and horseback.

After the invention of gunpowder the qualities of strength and agility became of less importance for the soldier, and athletic training was discontinued everywhere. But within the last few years the changing conditions of modern warfare have again demanded from the soldier a degree of endurance and of rapidity of movement which the wars of the eighteenth century did not require. And the population generally of this country have of late years become alive to the necessity of compensating, by some artificial system of muscular exercise, the sedentary life which so many lead.

In our own time, the first regular gymnasium appears to have been established at Schwefental, in Saxony, by Saltzmann, with a view of giving health to the body, strengthening certain muscles, and remedying deformities. About forty years ago Ling also commenced in Sweden the system of movements which have made his name so celebrated. Switzerland, Spain, and France followed, and of late years in Germany many gymnastic societies (Türner-Verein) have been founded in almost all the great cities, and the literature of gymnasticism is now a large one. In our own country, the out-door and vigorous life led by the richer classes, and by many working-men, rendered this movement less necessary, but of late years societies have been formed, gymnasia established, and athletic sports encouraged in many places.

Among armies, the Swedish and Prussian were the first to attempt the physical training of their soldiers. France followed in 1845, and ever since a complete system of gymnastic instruction has been carried on in the French army. Since the accession of Napoleon III., the greatest care has been taken to develop this plan of increasing the efficiency of the soldier, and a large military gymnastic school exists at Vincennes where instructors for the army are taught.

In the English army this matter attracted less attention until after the Crimean war, when the establishment of gymnasia as a means of training and recreation were among some of the many reforms projected by Lord Herbert. In 1859, General Hamilton and Dr Logan, Director-General of the Army Medical Department, were sent over to inspect the systems in use on the Continent, and presented a very interesting Report, which was subsequently published. A grant of money was immediately taken for a gymnasium at Aldershot, and this has now been in operation for several years, under the direction of Major Hammersley, with most satisfactory results. Gymnasia are now ordered to be built at all the large stations, and a complete code of instructions, drawn up by Mr MacLaren of Oxford, is published by authority.*

* A Military System of Gymnastic Exercises, by Archibald MacLaren, Adjutant-General's Office, Horse-Guards, 1862. Mr MacLaren has also published two other works of great utility;

Gymnastic Instruction in the English Army.

The instruction has two great objects—1*st*, To assist the physical development of the recruit; 2*d*, To strengthen and render supple the frame of the trained soldier. Every recruit is now ordered to have three months' gymnastic training during (or, if judged expedient by a medical officer, in lieu of part of) his ordinary drill. Two months are given before he commences rifle practice, and one month afterwards. This training is superintended by a medical officer, who will be responsible that it is done properly, and who will have the power to continue the exercises beyond the prescribed time, if he deems it necessary. The exercise for the recruit is to last only one hour a-day, and in addition he will have from two to three hours of ordinary drill.

The trained infantry soldier under ten years' service, is ordered to go through a gymnastic course of three months' duration every year, one hour being given every other day. The cavalry soldier is to be taught fencing and sword exercise in lieu of gymnastics.

The Code of Instructions drawn up by Mr MacLaren consists of two parts, elementary and advanced exercises. The exercises have been arranged with very great care, and present a progressive course of the most useful kind.

The early exercise commences with walking and running; leaping, with and without the pole, follows, and then the exercises with apparatus commence, the order being the horizontal beam, the vaulting bar, and the vaulting horse. All these are called exercises of progression. The elementary exercises follow, viz., with the parallel bars, the pair of rings, the row of rings, the elastic ladder, the horizontal bar, the bridge ladder, and the ladder plank. Then follow the advanced exercises of climbing on the slanting and vertical pole, the slanting and vertical rope, and the knotted rope.

Finally, the most advanced exercises consist of escalading, first against a wall, and then against a prepared building.

In the French army swimming and singing are also taught. Both are very useful; the singing is encouraged, not as a matter of amusement (though it is very useful in this way), but as a means of improving the lungs.

Swimming should be considered an essential part of the soldier's education, and it is probable that it will be systematically taught in the English army.

Robert Jackson very strongly recommended that dancing should be taught and encouraged. There is sound sense in this; a spirited dance brings into play many muscles, and in a well-aired room is as good an exercise as can be taken. It would also be an amusement for the men.

Effects of Gymnastic Training.

On Young Men under Twenty.—In the chapter on the Choice and Treatment of the Recruit, some particulars are given of the average size and growth up to the age of twenty, under ordinary circumstances, as far as these are known. Mr MacLaren has endeavoured to determine the ratio of growth at different ages under the influence of gymnastic training, but his observations are at present too few to enable a rule to be laid down.

On trained soldiers, the effect of gymnastic training is to increase largely the girth of the chest, and of the arms and legs. In some cases, also, even in grown men the height increases.

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a System of Training and Physical Education. This last work should be in the hands of every one.

SECTION V.

DUTIES OF THE OFFICER IN THE GYMNASIUM.

The Medical Regulations order the inspecting medical officer and surgeon to visit and advise on the kind and amount of gymnastic exercises. The Queen's Regulations (Para. 1360) order a strict medical examination of each man before the instruction is commenced. During the course further inspections are to be made; of the recruits once a fortnight; of trained soldiers monthly. The measurements of the recruit are also to be taken under the direction of the medical officer. The following points should be attended in regard to—

1. *Recruits.*—The recruit is inspected from time to time, to see if the system agrees with him.

(*a.*) *Weight.*—The weight of the body should be ascertained at the beginning and end of the course, and during it, if the recruit in any way complains. With sufficient food recruits almost always gain in weight, therefore any loss of weight should at once call for strict inquiry. It may be the recruit is being overdone, and more rest may be necessary. But in order to avoid the greatest error, the weights must be carefully taken; if they are taken at all times of the day, without regard to food, exercise, &c., accuracy is impossible; there may be 2 ℔ or 3 ℔ variation. The physiological practice during experiments is to take the weight the first thing in the morning before breakfast, and after emptying the bladder. If it cannot be done at this time, scarcely any reliance can be placed on the result. Food alone may raise the weight 2 ℔ or 3 ℔, and we cannot be sure that the same quantity of food is taken daily. The clothes, also, must be remembered; men should be weighed naked if possible, if not, in their trousers only, and always in the same dress.

(*b.*) *Height.*—This is usually taken in the erect position. Dr Aitken* recommends it to be taken when the body is stretched on a horizontal plane. A series of experiments on both plans would be very desirable.

(*c.*) *Girth of Chest.*—The chest is measured to ascertain its absolute size, and its amount of expansion.

It is best measured when the man stands at attention, with the arms hanging; and the tape should pass round the nipple line. The double tape (the junction being placed on the spine) is a great improvement over the single tape, as it measures the sides separately, and with practice can be done as quickly.

The chest should be measured in the fullest expiration and fullest inspiration. If the chest is measured with the arms extended, or over the head, as ordered in the Regulations in Recruiting, the scapulæ may throw out the tape from the side of the chest.

(*d.*) *The Inspiratory Power*, as expressed by the spirometer, may also be employed.

(*e.*) *Growth of Muscles.*—This is known by feeling the muscles when relaxed and in action, and by measurements. The measurement of the upper arm should be taken either when the arm is bent over the most prominent part of the biceps, or over the thickest part when the arm is extended.

(*f.*) *General Condition of Health.*—Digestion, sleep, complexion, &c. The recruit should also be inspected during the time of exercise to watch the effect on his lungs, heart, and muscles. In commencing training the great point is to educate, so to speak, the heart and lungs to perform suddenly without injury a great amount of work. To do this there is nothing better

* On the Growth of the Recruit, p. 68.

than practice in running and jumping. It is astonishing what effect this soon has. If possible, the increase in the number of respirations after running 200 or 300 yards should be noted on the first day, as this gives a standard by which to judge of the subsequent improvement. But as it would be impossible and a waste of time to do this with all the men, directly the run is ended the men should range in line, and the medical officer should pass rapidly down and pick out the men whose respiration is most hurried. In all the exercises the least difficulty of respiration should cause the exercise to be suspended for four or five minutes.* The heart should be watched; the characters indicating the necessity for rest or easier work are excessive rapidity (130–160), smallness, inequality, and irregularity.

Soreness of muscles after the exercise, or great weariness, should be inquired into. It would be well every now and then to try the inguinal and femoral rings during exertion and coughing.

One very important part in gymnastic training depends on the instructor. A good instructor varies the work constantly, and never urges a man to undue or repeated exertion. If the particular exercise cannot be done by any man it should be left for the time. Anything like urging or jeering by the rest of the men should be strictly discountenanced. The instructor should pass rapidly from exercise to exercise, so that a great variety of muscles may be brought into play for a short time each, and as the men work in classes, and all cannot be acting at once, there is necessarily a good deal of rest.

The grand rule for an instructor is, then, change of work and sufficient rest.

In the case of a recruit who has not been used to much physical exertion, the greatest care must be taken to give plenty of rest during the exercises. There may even seem to be an undue proportion of rest for the first fortnight, but it is really not lost time. The medical officer is only directed to visit the gymnasium once a fortnight, but during the first fortnight of the training of a batch of recruits he should visit it every day.

With proper care men are very seldom injured in gymnasia. I was informed at Vincennes that though they did not take men unless they were certified as fit by a medical officer, they occasionally got men with "delicate chests," though not absolutely diseased. These men always improved marvellously during the six months they remained at Vincennes. In fact, a regulated course of gymnastics is well known to be an important remedial measure in threatened phthisis. Hernia is never caused at Vincennes. Nor does it appear that any age is too great to be benefited by gymnastics, though in old men the condition of the heart and vessels (as to rigidity) should be looked to.

Trained Soldiers.—There is less occasion for care with these men; they should, however, be examined from time to time, and any great hurry of respiration noted. The man should be called out from the class, his heart examined, and some relaxation advised if necessary.

SECTION VI.

DRILLS AND MARCHES.

In drill, and during marches, the movements of the soldiers are to a certain extent constrained. In the attitude of "attention" the heels are close together,

* In the training of horses the points always attended to are—the very gradual increase of the exercise; gentle walking is persevered in for a long time, then slow gallops, then, as the horse gains wind and strength, quicker gallops; but the horse is never distressed, and a boy would be dismissed from a stable if it were known that the horse he was riding showed by sighing, or in any other way, that the speed was too great for him.

the toes turned out at an angle of 60°, the arms hang close by the sides, the thumbs close to the forefingers and on a line with the seam of the trousers. The position is not a secure one, as the basis of support is small, and in the manual and platoon exercise the constant shifting of the weight changes the centre of gravity every moment, so that constant muscular action is necessary to maintain the equilibrium. Men are therefore seldom kept long under attention, but are told to "stand at ease" and "stand easy," in which cases, and especially in the latter, the feet are farther apart and the muscles are less constrained.

In marching the attitude is still stiff—it is the position of attention, as it were, put into motion. The slight lateral movement which the easy walker makes when he brings the centre of gravity alternately over each foot, and the slight rotary motion which the trunk makes on the hip-joint, is restrained as far as it can be, though it cannot be altogether avoided, as is proved by observing the slight swaying motion of a line of even very steady men marching at quick time. Marching is certainly much more fatiguing than free walking; and in the French army, and by many commanding officers in our own, the men are allowed to walk easily and disconnectedly, except when closed up for any special purpose. This may not look so striking to the eye of a novice, but to the real soldier, whose object is at the end of a long march to have his men so fresh that, if necessary, they could go at once into action, such easy marching is seen to be really more soldierlike than the constrained attitudes which lead so much sooner to the loss of the soldier's strength and activity.

In walking, the heel touches the ground first, and then rapidly the rest of the foot, and the great toe leaves the ground last. The soldier, in some countries, is taught to place the foot almost flat on the ground, but this is a mistake, as the body loses in part the advantage of the buffer-like mechanism of the heel. The toes are turned out at an angle of about 30° to 45°, and at each step the leg advances forward and a little outward; the centre of gravity, which is between the navel and the pubis, about in a line with the promontory of the sacrum (Weber), is constantly shifting. It has been supposed that it would be of advantage to keep the foot quite straight, or to turn the toes a little in, and to let the feet advance almost in a line with each other. But the advantage of keeping the feet apart and the toes turned out, is that, first, the feet can advance in a straight line, which is obviously the action of the great *vasti* muscles in front of the thigh; and, second, when the body is brought over the foot, the turned-out toes give a much broader base of support than when the foot is straight. The spring from the great toe may perhaps be a little greater when the foot is straight (though of this I am not certain, and I do not see why the gastrocnemii and solei should contract better in this position), but there is a loss of spring from the other toes. Besides this, it has been shown by Weber that when the leg is at its greatest length, *i.e.*, when it has just urged the body forward, and is lifted from the ground, it falls forward like a pendulum from its own weight, not from muscular action, and this advance is from within and behind to without and before, so that this action alone carries the leg outwards.

The foot should be raised from the ground only so far as is necessary to clear obstacles. Formerly, in the Russian Imperial Guard, the men were taught to march with a peculiar high step, the knee being lifted almost to a level with the acetabulum. The effect was striking, but the waste of power was so great that long marches were impossible, and I believe this kind of marching is now given up. The foot should never be advanced beyond the place where it is to be put down; to do so is a waste of labour.

In the English army the order is as follows :—

Length and Number of Steps in Marching.

Kind of Step.	Length.	No. per Minute.	Ground Traversed per Minute.	Ground Traversed per Hour without Halts.
	Inches.		Feet.	Miles.
Slow time, . .	30	75	187½	2·1
Quick time, . .	30	110	275	3·1
Stepping out, .	33	110	303½	3·4
Double, . . .	36	150	450	5·1
Stepping short, .	10	...	...	...
Side step, . .	10	...	...	...
or when Forming four deep,	21	...	...	...
Stepping back, .	30	...	...	...

The "double" is never continued very long; it is stopped at the option of the commanding officer. In the French army it is ordered not to be continued longer than twenty minutes.* At the double (if without arms), the forearms are held horizontally, the elbows close to the side; if the rifle is carried, one arm is so held. There is an advantage in this attitude, as the arms are brought into the position of least resistance; more fixed points are given for the muscles of respiration, and the movement of the arms and shoulders facilitates the rapid shifting of the centre of gravity.

Quick time is always used in drills and marching. The ground got over per hour is generally reduced by halts to 2·8 miles.

Running drill has been lately introduced; it is not carried beyond 1000 yards, and the men are gradually brought up to this amount. The pace is not to exceed 6 miles an hour. All men over 15 years' service and weakly men (if considered unfit by the medical officers), are to be excused (Queen's Reg. 1377).

In the French army the length of the step is rather different.

French Steps in English Measures.

	Length of Step in Inches.	Steps per Minute.	Ground Traversed per Minute in Feet.	Ground Traversed per Hour in Miles.
Pas ordinaire, .	26	76	164	1·86
Pas de route, .	26	100	216	2·46
Pas accéléré, .	26	110	238	2·70
Pas accéléré, .	26	120	260	2·95
Pas de charge, .	26	128	277	3·15
Pas maximum, .	26	153	331	3·76

* It may be worth while to mention some of the feats of celebrated pedestrians as a means of comparison.

The mile has been walked in 7 minutes (or at the rate of 8½ miles per hour). Such an exertion is enormous, for the exertion is in the ratio of the velocity.

Ten miles have been walked by Captain Saunders in 93½ minutes, and 21 miles in 3 hours by Westhall.

In running, 100 yards have been covered in 9¼ seconds; a little over 10 sec. is the usual time.

½ mile in	1 minute 58 seconds.
1 mile in	4 minutes 22¼ ,,
2 miles in	9 minutes 20 ,,
6 ,,	31 ,,
10 ,,	51 ,,
11 ,, and 46 yards	60 ,,
20 ,,	120 ,,
40 ,,	5 hours.
100 ,,	18 hours and 50 minutes.

The French step is therefore 4 inches shorter than the English; this is perhaps because the men are, as a rule, shorter. The Prussian and the Bavarian step is 30 inches (Prussian) long, and 120 steps are taken per minute.

The exact length of the step, and the number per minute, are very important questions. The object of the soldier is to get the step as long, and the number per minute as great, as possible, without undue fatigue, so as to get over the greatest amount of ground.

The quickest movement of the leg forward in walking has been shown by Weber to correspond very closely with half a pendulum vibration of the leg, and to occupy, on an average, 0·357 seconds; this would give 168 steps per minute, supposing the one foot left the ground when the other touched it. This is much quicker than the army walking step (the double is a run), and no doubt much quicker than could long be borne, since, with a step of only 30 inches, it would give nearly 5 miles per hour; but it may be a question whether, with men in good condition, the pace might not be increased to 130 per minute. Practical trials, however, with soldiers carrying arms and accoutrements can only decide this point.

The length of the step of an average man has been fixed by the Brothers Weber at about 28 inches. In individual cases, it depends entirely on the length of the legs. Robert Jackson considered 30 inches as too long a step for the average soldier, and suggested 27 inches. It is of great importance not to lessen the length too much, and it would be very desirable to have some well-conducted experiments on this point. The steps must be shorter if weights are carried than without them; a little consideration shows how this is: When a man walks, he lifts his whole body and propels it forward, and in doing so, the point of centre of gravity describes a circular motion, in the form of an arc about the foot.

Now, the less the body is raised, or, in other words, the shorter the versed sine of the arc, the less of course the labour. In long steps, the arc, and of course the versed sine, or height to which the body is raised, are greater; in short steps, less. It is probable that, with the weight the soldier carries (60 ℔), the step of 30 inches is quite long enough, perhaps even too long; and it would be desirable to know if, after a march of six or eight miles, the steps do not get shorter.

In the French army, the march is commenced at the *pas de route* (100 steps per minute); then accelerated to 110 steps, and finally to 130; during the last half-hour 100 steps are returned to. But the soldiers themselves often set the step; the grenadiers and the voltigeurs alternately leading. Four kilometres (= $2\frac{1}{2}$ miles) are done in forty-five or forty-eight minutes. One kilometre (= 0·62 miles) is done in about twelve minutes.

The soldier, in this country, when he marches in time of peace in heavy order, carries his pack, kit, haversack, water-bottle, greatcoat, rifle, and ammunition (probably twenty rounds). In India, he does not carry his pack or greatcoat.

There is a very general impression that the best marchers are men of middle size, and that very tall men do not march so well.

Length of the March.—In "marching out" in time of peace, which is done once or twice a-week in the winter, the distance is six or eight miles. In marching on the route or in war, the distance is from ten or twelve miles to occasionally eighteen or twenty, but that is a long march. A forced march is any distance—twenty-five to thirty, and occasionally even forty miles being got over in twenty-four hours. In the Prussian army the usual march is fourteen miles (English); if the march is continuous, there is a halt every fourth day.

A halt is usually made every hour for five minutes, and fifteen minutes after

the second hour. In a long march, an hour's halt is made in the middle. In the French army halts are frequent during the first days, but when the men are fully trained they take place only every two hours.

In marching long distances, the extent of the marches, the halting grounds, &c., are fixed by the Quartermaster's department.

Robert Jackson considered that an ordinary march should be fourteen miles, and done in four hours and twenty-five minutes, including halts, at the rate of three and four miles an hour, the first hour to be at slow time, with five minutes' halt; the march to be at quick time, with fifteen minutes' halt at the end of the second hour; in the third hour slow time to be resumed; an hour's halt to be given after two or three hours. Officers of experience, however, have informed me that the slow time is not a good plan; it is better not to let the men drawl on the pace, but to give them more frequent halts, if necessary, to get their wind.

Occasionally the march has been divided, one part being done in the early morning, and the remainder late in the afternoon. It is, however, better to make the march continuous, and, if necessary, to lengthen the mid-day halt.

Order of March.—Whenever possible, it seems desirable to march in open order. Inspector-General J. R. Taylor has given evidence to show that a close order of ranks is a cause of unhealthiness in marching, similar to that of overcrowding in barracks; and the Medical Board of Bengal have, in accordance with this opinion, recommended that military movements in close order should be as little practised as possible.* There should also be as much interval as can be allowed between bodies of troops.

Effects of Marches.—Under ordinary conditions, both in cold and hot countries, men are healthy on the march. The exercise, the free air, the change of scene—all do good. Under special circumstances, immense marches have been made by all armies. The French and Spanish are particularly good marchers, the British less so; but they have occasionally made extraordinary efforts.

One of the most celebrated in the annals of the British Army is the march made by the 43d, 52d, and 95th Regiments of Foot, under Crawfurd, in July 1809, in Spain, in order to reinforce Sir Arthur Wellesley at the battle of Talavera. About fifty weakly men were left behind, and the brigade then marched sixty-two miles in twenty-six hours, carrying arms, ammunition, and pack—in all, a weight of between 50 ℔ and 60 ℔.† There were only seventeen stragglers. The men had been well trained in marching during the previous month.

One of these regiments—the 52d—made in India, in 1857, a march as extraordinary. In the height of the mutiny, intelligence reached them of the locality of the rebels from Sealkote. The 52d, and some artillery, started at night on the 10th of July 1857 from Umritzur, and reached Goodasepore, forty-two miles off, in twenty hours, some part of the march being in the sun. On the following morning they marched ten miles, and engaged the mutineers. They were for the first time clad in the comfortable gray or dust-coloured native Khakee cloth.

Forced marching for some days may be also well borne by seasoned troops,

* Chevers, *op. cit.*, p. 98.

† Napier's "War in the Peninsula," 3d edit. vol. ii. p. 400; Moorsom's "Record of the 52d Regiment," p. 115. Both authors state that the men carried between 50 ℔ and 60 ℔ on this extraordinary march, but there seems a little doubt of this. During the Peninsular war the men carried bags, weighing about 2 ℔, and not framed packs, and their kits were very scanty. Lord Clyde, in talking of this march to my colleague, Mr Longmore, told him the men only carried a shirt and a spare pair of either boots or soles. He saw the men march in. In all probability, also, they would not carry their full ammunition.

as in the case of two companies of the 39th, which accomplished 195 miles in nine days (=21·6 miles daily) in Canara in India, in the month of April, without a casualty.

Thirty miles a-day for four or five days appear also to have been done by some European regiments during the mutiny without loss at the time, though there was often much sickness afterwards.

But marches are sometimes hurtful—

1*st*, When a single long and heavy march is undertaken when the men are overloaded, without food, and perhaps without water. The men fall out, and the road becomes strewed with stragglers. Sometimes the loss of life has been great.

The prevention of these catastrophes is easy. Place the soldier as much as possible in the position of the professional pedestrian; let his clothes and accoutrements be adapted to his work; supply him with water and proper food, and exclude spirits; if unusual or rapid exertion is demanded, the weights must be still more lightened.

When a soldier falls out on the march he will be found partially fainting, with cold moist extremities, a profuse sweat everywhere; the pulse is very quick and weak—often irregular; the respiration often sighing. The weights should be removed, clothes loosened, the man laid on the ground, cold water dashed on the face, and water given to drink in small quantities. If the syncope is very dangerous, brandy must be used as the only way of keeping the heart acting, but a large quantity is dangerous. If it can be obtained, weak hot brandy and water is the best under these circumstances. When he has recovered, the man must not march—he should be carried in a waggon, and in a few minutes have something to eat, but not much at a time. Concentrated beef-tea mixed with wine is a powerful restorative, just as it is to wounded men on the field.

2*d*, When the marches which singly are not too long are prolonged over many days or weeks without due rest.

With proper halts men will march easily from 500 to 1000 miles, or even farther, or from twelve to sixteen miles per diem, and be all the better for it; but after the second or third weeks, there must be one halt in the week besides Sunday. If not, the work begins to tell on the men; they get out of condition, the muscles get soft, appetite declines, and there may be even a little anæmia. The same effects are produced with a much less quantity of work, if the food is insufficient. Bad food and insufficient rest are then the great causes of this condition of body.

In such a state of body malarious fevers are intensified, and in India attacks of cholera are more frequent. It has been supposed that the body is overladen with the products of metamorphosis which cannot be oxidised fast enough to be removed.

Directly the least trace of loss of condition begins to be perceived in the more weakly men (who are the tests in this case), the surgeon should advise the additional halt, if military exigencies permit. On the halt day the men should wash themselves and their clothes, and parade, but should not drill.

3*d*, When special circumstances produce diseases.

Exposure to wet and cold in temperate climates is the great foe of the soldier. As long as he is marching, no great harm results; and if at night he can have dry and warm lodgings, he can bear, when seasoned, great exposure. But if he is exposed night as well as day, and in war he often is so, and never gets dry, the hardiest men will suffer. Affections arising from cold, catarrhs, rheumatism, pulmonary inflammation, and dysentery are caused.

These are incidental to the soldier's life, and can never be altogether

avoided. But one great boon can be given to him; a waterproof sheet, which can cover him both day and night, has been found the greatest comfort by those who have tried it. (See chapter on CLOTHING.)

The soldier may have to march through malarious regions. The march should then be at mid-day in cold regions, in the afternoon in hot. The early morning marches of the tropics should be given up for the time; the deadliest time for the malaria is at and soon after sunrise. If a specially deadly narrow district has to be got through, such as a Terai, at the foot of hills, a single long march should be ordered; a thoroughly good meal, with wine, should be taken before starting, and if it can be done, a dose of quinine. If the troops must halt a night in such a district, every man should take five grains of quinine. Tents should be pitched in accordance with the rules laid down in the chapter on CAMPS, and the men should not leave them till the sun is well up in the heavens.

Yellow fever or cholera may break out. The rules in both cases are the same. At once leave the line of march; take a short march at right angles to the wind; separate the sick men, and place the hospital tent to leeward; let every evacuation and vomited matter be at once buried and covered with earth, and employ natives (if in India) to do this constantly, with a sergeant to superintend. Let every duty-man who goes twice to the rear in six hours report himself, and, if the disease be cholera, distribute pills of acetate of lead and opium to all the non-commissioned officers. Directly a man who becomes choleraic has used a latrine, either abandon it, or cover it with earth and lime if it can be procured. If there is carbolic acid or chloride of zinc, or lime or sulphate of iron or zinc at hand, add some to every stool or vomit.

In two days, whether the cholera has stopped or not, move two miles; take care in the old camp to cover everything, so that it may not prove a focus of disease for others. The drinking water should be constantly looked to. A regiment should never follow one which carries cholera; it should avoid towns where cholera prevails; if it itself carries cholera, the men should not be allowed to enter towns. I know one instance (and many are known in India) where cholera was in this way introduced into a town.

The men may suffer from insolation. This will generally be under three conditions.* Excessive solar heat in men unaccustomed to it and wrongly dressed, as in the case of the 98th in the first China war, when the men having just landed from a six months' voyage, and being buttoned up and wearing stocks, fell in numbers during the first short march. A friend who followed with the rearguard informed me that the men fell on their faces as if struck by lightning; on running up and turning them over, he found many of them already dead. They had, no doubt, struggled on to the last moment. This seems to be intense asphyxia, with sudden failure of the heart-action, and is the "cardiac variety" of Morehead.

A dress to allow perfectly free respiration (freedom from pressure on chest and neck), and protection of the head and spine from the sun, will generally prevent this form. The head-dress may be wetted from time to time, a piece of wet paper in the crown of the cap is useful. When the attack has occurred, cold affusion, artificial respiration, ammonia, and hot brandy and water to act on the heart seem the best measures. Bleeding is hurtful; perhaps fatal. Cold affusion must not be pushed to excess.

In a second form the men are exposed to continued heat,† both in the sun

* Of course I do not enter here into the pathology of this affection. For this I refer to the great works of Morehead and Martin and Aitken. I look at it from a special point of view.

† The heat of sandy plains is the worst, probably, from the great absorption of heat and the continued rarefaction. The heat of the sun, *per se*, is not so bad; on board ship sun-stroke is uncommon.

and out of it, day and night, and the atmosphere is still, and perhaps moist, so that evaporation is lessened, or the air is vitiated. If much exertion is taken, the freest perspiration is then necessary to keep down the heat of the body; if anything checks this, and the skin gets dry, a certain amount of pyrexia occurs; the pulse rises; the head aches; the eyes get congested; there is a frequent desire to micturate (Longmore), and gradual or sudden coma, with perhaps convulsions and stertor, comes on, even sometimes when a man is lying quiet in his tent. The causes of the interruption to perspiration are not known; it may be that the skin is acted upon in some way by the heat, and from being over-stimulated, at last becomes inactive.

In this form cold affusion, ice to the head, and ice taken by the mouth, are the best remedies; perhaps even ice water by the rectum might be tried. Stimulants are hurtful. The exact pathology of this form of insolation is uncertain. It is the cerebro-spinal variety of Morehead.

In a third form a man is exposed to a hot land-wind; perhaps, as many have seen, from lying drunk without cover. When brought in, there is generally complete coma with dilated pupils, and a very darkly flushed face. After death the most striking point is the enormous congestion of the lungs, which is also marked, though less so, in the other varieties. Although I have dissected men in a very large number of diseases both in India and England, I have never seen anything like the enormous congestion I have observed in two or three cases of this kind.

As prevention of all forms, the following points should be attended to—suitable clothing; plenty of cold drinking water (Crawford); ventilation; production in buildings of currents of air; bathing; avoidance of spirits; lessening of exertion demanded from the men.

SECTION VII.

DUTIES OF MEDICAL OFFICERS DURING MARCHES.

General Duties on Marches in India or the Colonies.—Before commencing the march, order all men with sore feet to report themselves. See that all the men have their proper kits, neither more nor less. Every man should be provided with a water-bottle to hold not less than a pint. Inspect halting-grounds, if possible; see that they are perfectly clean, and that everything is ready for the men. In India, on some of the trunk roads there are regular halting-grounds set apart. The conservancy of these should be very carefully looked to, else they become nothing but foci for disseminating disease. If there are no such places, halting-grounds are selected. It should be a rule never to occupy an encamping ground previously used by another corps if it can be avoided; this applies to all cases. Select a position to windward of such an old camp, and keep as far as possible from it. The encampment of the transport department, elephants, camels, bullock carts, &c., must be looked to,—they often are very dirty: keep them to leeward of the camp, not too near, and see especially that there is no chance of their contaminating streams supplying drinking water. If the encampment is on the banks of a stream, the proper place for the native camp and bazaar will always be lower down the stream. The junior medical officer, if he can be spared, should be sent forward for this purpose with a combatant officer. Advise on length of marches, halts, &c., and draw up a set of plain rules to be promulgated by the commanding officer, directing the men how to manage on the march if exposed to great heat or cold, or to long-continued exertion, how to purify water, clean their clothes, &c. If the march is to last some time, and if halts

are made for two or three days at a time, write a set of instructions for ventilating and cleaning tents, regulations of latrines, &c.

Special Duties for the March itself.—Inspect the breakfast or morning refreshment; see that the men get their coffee, &c. On no account allow a morning dram, either in malarious regions or elsewhere. Inspect the water-casks, and see them properly placed, so that the men may be supplied; inspect some of the men, to see that the water-bottles are full. March in rear of the regiment so as to pick up all the men that fall out, and order men who cannot march to be carried in waggons, dhoolies, &c., or to be relieved of their packs, &c. If there are two medical officers, the senior should be in rear; if a regiment marches in divisions, the senior is ordered to be with the last. When men are ordered either to be carried or to have their packs carried, tickets should be given specifying the length of time they are to be carried. These tickets should be prepared before the march, so that nothing has to be done but to fill in the man's name, and the length he is to be carried.

Special orders should be given that, at the halt, or at the end of the day's march, the heated men should not uncover themselves. They should take off their pack and belts, but keep on the clothes, and, if very hot, should put on their greatcoats. The reason of this (viz., the great danger of chill *after* exertion) should be explained to them. In an hour after the end of the march the men should change their underclothing, and hang the wet things up to dry; when dry they should be shaken well, and put by for the following day. Some officers, however, prefer that their men should at once change their clothes and put on dry things. This is certainly more comfortable. But, at any rate, exposure must be prevented.

It will be found that old soldiers eat very little while on the march; the largest meal is taken at the end.

At the end of the march inspect the footsore men.

Footsoreness is generally a great trouble, and frequently arises from faulty boots, undue pressure, chafing, riding of the toes from narrow soles, &c. Rubbing the feet with tallow, or oil or fat of any kind,* before marching, is a common remedy. A good plan is to dip the feet in very hot water, before starting, for a minute or two; wipe them quite dry, then rub them with soap (soft soap is the best), till there is a lather; then put on the stocking. At the end of the day, if the feet are sore, they should be wiped with a wet cloth, and rubbed with tallow and spirits mixed in the palm of the hand (Galton). Pedestrians frequently use hot salt and water at night, and add a little alum. Sometimes the soreness is owing simply to a bad stocking; this is easily remedied. Stockings should be frequently washed; then greased. Some of the German troops use no stockings, but rags folded smooth over the feet. This is a very good plan. Very often soreness is owing to neglected corns, bunions, or in-growing nails, and the surgeon must not despise the little surgery necessary to remedy these things; nothing, in fact, can be called little if it conduces to efficiency.

As shoes are often to blame for sore feet, it becomes a question whether it might not be well to accustom the soldier to do without shoes. (See section on Shoes.)

Frequently men fall out on the march to empty the bowels; the frequency with which men thus lagging behind the column were cut off by Arabs, led the French in Algeria to introduce the slit in the Zouave trousers, which require no unbuckling at the waist, and take no time for adjustment.

* An old prejudice gives the preference to stag's fat, but there is little doubt all oils are equally effectual.

At the long halt, if there is plenty of water, the shoes and stockings should be taken off, and the feet well washed; even wiping with a wet towel is very refreshing. The feet should always be washed at the end of the march.

Occasionally men are much annoyed with chafing between the nates or inside of the thighs. Sometimes this is simply owing to the clothes, but sometimes to the actual chafing of the parts. Powders are said to be the best —flour, oxide of zinc, and above all, it is said, fuller's earth.

If blisters form on the feet, the men should be directed not to open them during the march, but at the end of the time to draw a needle and thread through; the fluid gradually oozes out.

All footsore men should be ordered to report themselves at once.

Sprains are best treated with rags dipped in cold water, or cold spirit and water with nitre, and bound tolerably tightly round the part. Rest is often impossible. Hot fomentations, when procurable, will relieve pain.

Marches, especially if hurried, sometimes lead men to neglect their bowels, and some trouble occurs in this way. As a rule, it is desirable to avoid purgative medicines on the line of march, but this cannot always be done; they should, however, be as mild as possible.

Robert Jackson strongly advised the use of vinegar and water as a refreshing beverage, having probably taken this idea from the Romans, who made vinegar one of the necessaries of the soldier. It was probably used by them as an anti-scorbutic; whether it is very refreshing to a fatigued man I do not know.

There is only one occasion when spirits should be issued on the march: this is on forced marches, near the end of the time, when the exhaustion is great. A little spirit, in a large quantity of hot water, may then be useful, but it should only be used on great emergency. Warm beer or tea is also good; the warmth seems an important point. Ranald Martin tells us that in the most severe work in Burmah, in the hot months of April and May, and in the hot hours of the day, warm tea was the most refreshing beverage. This I found also from my own experience. Several friends have told me that both in India, and in bush travelling in Australia, there was nothing so reviving as warm tea. Chevers mentions that the juice of the country onion is useful in lessening thirst during marches in India, and that, in cases of sun-stroke, the natives use the juice of the unripe mangoe mixed with salt.

Music on the march is very invigorating to tired men. Singing should also be encouraged as much as possible.

Marching in India.—Very little need be said in addition to the general rules just laid down. Marches take place in the cool season (November to February), and not in the hot or rainy seasons, except on emergency; yet marches have been made in hot weather without harm, when care is taken. They are conducted much in the same way as in cold countries, except that the very early morning is usually chosen. The men are roused about half-past two or three, and parade half an hour later; the tents are struck, and carried on by the tent-bearers; coffee is served out, and the men march off by half-past three or four, and end at half-past seven. Everything is ready at the halting-ground, tents are pitched, breakfast is prepared.

These very early marches are strongly advocated by many, and are opposed almost as strongly as some. Sir George Ballingall was of opinion that the disturbance of the men's sleep was worse than the exposure to the sun till ten or eleven o'clock would be. In the West Indies, marching in the sun has always been more common than in the East. Much, perhaps, must depend on the locality, and the prevalence and time of hot land-winds. (See CLIMATE.)

In malarious districts there can be no question that the early morning is the worst time; in the heat of the day the risk of malaria is trifling.

Both in India and Algeria marches have been made at night; the evidence of the effects of this is discordant. The French have generally found it did not answer; men bear fatigue less well at night; and it is stated that the admissions into hospital have always increased among the French after night marching. Annesley's authority is also against night marching in India. On the other hand, I have been informed that in India the march through the cool moonlight night has been found both pleasant and healthy.

Afternoon marches (commencing about two hours before sunset) have been tried in India, and, I believe, often with very good results. It seems very desirable to give this plan a fair trial.

The halting-grounds in India are generally indicated beforehand by the Quartermaster-General's department, and on some of the trunk roads there are regular walled spaces set apart for this purpose.

Marching in Canada.—In 1814, during the war with America; in 1837, during the rebellion; and, in 1861–62, during the "Trent" excitement, winter marches were made by the troops, in all cases without loss. The following winter clothing was issued at home,—a sealskin cap with ear lappets; a woollen comforter; two woollen jersies; two pair woollen drawers; a chamois leathern vest with arms; two pair long woollen stockings to draw over the boots; sealskin mits, and a pair of jackboots. In Canada a pair of blankets and moccasins were added,* and, at the long halts, weak hot rum and water was served out. A quarter of a pound of meat was added to the ration. A hot meal was given before starting, another at mid-day, and another at night. The troops were extremely healthy, only 70 men were admitted into the hospitals on route out of a strength of 6818; there were 11 cases of frostbite, and 7 of pneumonia. During exposure to cold, spirits must be avoided; hot coffee, tea, ginger tea, or hot weak wine and water, are the best. In all cases the warmth of the drink is important.

During great exposure to cold it is a good plan to rub the hands, feet, face, and neck with oil; it appears to lessen the radiation of heat and the cooling effect of winds. Alpine travellers find a piece of blotting paper, cut to the shape of the sole of the foot, and placed in the stocking, a good plan.

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* See Inspector-General Muir's Report—Army Medical Report, vol. iv. p. 378.

CHAPTER XIV.

CLOTHING.

Regulations.—No specific instructions are laid down in the Medical Regulations respecting clothing, but the spirit of the general sanitary rules necessarily includes this subject also. When an army takes the field, the Director-General is directed to issue a code for the guidance of medical officers, in which clothing is specifically mentioned; and the sanitary officer with the force is ordered to give advice in writing to the commander of the forces, on the subject of clothing among other things.

Formerly a certain sum, intended to pay for the clothing of the men, was allotted by Government to the colonels of regiments. This was a relic of the old system by which regiments were raised—viz., by permitting certain persons to enlist men, and assigning to them a sum of money for all expenses. The colonel employed a contractor to find the clothes, and received from him the surplus of the money after all payments had been made. A discretionary power rested with the service officers of the regiment, who could reject improper and insufficient clothing, and thus the interests of the soldier were in part protected.* The system was evidently radically bad in principle, and, since the Crimean war, the Government has been gradually taking this department into its own hands, and a large establishment has been formed at Pimlico, where the clothing for a certain number of regiments is prepared. This system has worked extremely well; the materials have been both better and cheaper, and important improvements have been and are still being introduced into the make of the garments, which cannot fail to increase the comfort and efficiency of the soldier.†

At the Pimlico depôt the greatest care is taken to test all the materials and the making up of the articles; the viewers are skilled persons, who are in no way under the influence of contractors.

In January 1865 a warrant was issued‡ containing the regulations for the clothing of the army.

SECTION I.

When a soldier enters the army he has to pay for his kit;§ some articles are subsequently supplied by Government, others he makes good himself. In the infantry of the line a careful soldier can keep his kit in good order at a cost of about L.1 per annum. The following are the articles of the kit supplied to the infantry recruit:—

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* But this safeguard was not sufficient. Officers are not judges of excellence of cloth; for this it requires special training. As Robert Jackson said fifty years ago: "Soldiers' clothing is inspected and approved by less competent judges than those who purchase for themselves."

† Much is owing to the exertions of Sir Thomas Troubridge, C.B., and Colonel Daubeney, C.B., who have had the organisation of this important establishment. Colonel A. Herbert has also much improved some important articles of clothing.

‡ Revised Royal Clothing Warrant, 1865.

§ It was supplied to him free of expense, but a late order has altered this.

Articles of the Kit (Infantry).

1 Forage cap.	1 Razor.
1 Shell-jacket.	Mitts.
1 Stock.	Knife, fork, and spoon.
2 Flannel shirts.*	Sponge.
3 Pairs socks.	Blacking (one tin).
2 Towels.	1 Clothes-brush.
1 Knapsack.	2 Shoe-brushes.
2 Pairs boots.	1 Shaving-brush.
1 Pair braces.	1 Button-stick.
1 Comb.	1 Hold-all.

To the Army Hospital Corps and Artillery, a waterproof bag, for part of the kit, is also issued to each man. Squad bags are issued to infantry, four to each company, to hold the surplus kit.

The kit is divided (Queen's Regulations, section 10, par. 608) into the surplus and the service kit. The former, consisting of 1 shell-jacket, 1 pair of socks, 1 shirt, 1 towel, 2 brushes, and such articles for the hold-all as are not wanted, is carried for the men. The service kit is supposed to be carried by the man, either on his person or in his knapsack (see EQUIPMENT).

Certain articles are also issued free of expense at stated intervals. For the particulars of these, reference must be made to the Royal Warrant of 1865, where they are stated in detail. The following are the articles issued to the line infantry soldier at home :—

One shaco and cover,	Triennially.
One tunic,	Annually.
One pair cloth trousers,	Annually.
One pair serge trousers in line regiments, or one pair tartan trousers in rifle regiments,	Biennially.
Two pairs of boots, one on 1st April and one on 1st October,	Annually.
One silk sash for serjeants,	Every two years.
One worsted sash for serjeants,	Every two years.

In India and the West Indies, and other tropical stations, light clothing of different kinds is used—drill trousers and calico jackets, or in India complete suits of the khakee, a native grey or dust-coloured cloth, or tunics of red serge, and very light cloth. The khakee is said not to wash well, and white drill is superseding it. The English dress is worn on certain occasions, or in certain stations. Formerly the home equipment was worn even in the south of India; but now the dress is much better arranged, and also differences of costume for different places and different times of the year are being introduced.

During Campaigns extra clothing is issued according to circumstances. In the Crimea the extra clothing was as follows for each man :—

2 Jersey frocks.	1 Cholera belt.
2 Woollen drawers.	1 Fur cap.
2 Pairs woollen socks.	1 Tweed lined coat.
2 Pairs woollen mitts.	1 Comforter.

To each regiment also a proportion of sheepskin coats was allowed for sentrics.

* By a circular, November 1865, flannel shirts only are ordered to be supplied to the recruit.

The warrant of 1865 orders the following articles of clothing to be issued to every 100 men proceeding on active service in cold, temperate, or hot climates :—

1. *In cold climates*—

	Per 100 effectives.		Per 100 effectives.
Sheepskin coats, ...	8	Stockings, woollen, . pairs,	200
Fur caps, ...	100	Drawers, flannel, . . „	200
Woollen comforters, . . .	100	Cholera belts, flannel,	200
Shirts, grey flannel, . . .	200	Mittens, lined with lambskin or fur, ... pairs,	100
Jerseys, blue, ...	100		
Boots, knee, brown leather, pairs,	100		

2. *In temperate climates*—

Shirts, flannel, of a light texture,	200	Waterproof capes, ...	10
Cholera belts, when not included in the voyage kit, . . .	200	Watch coats, ...	3

3. *In tropical climates*—

Shirts, flannel, of lightest texture, ...	200
Chaco covers, of white cotton, except in climates where the wicker helmet and "Puggaree" (turban) are to be worn, . .	100
Forage cap covers, of white cotton, ...	100
Frock coats, of red, green, or blue serge, when not supplied as ordinary clothing of these climates, ...	100
Cholera belts, of flannel, when not part of the sea kit, . .	200
Capes, waterproof, ...	10

SECTION II.

OBJECTS OF CLOTHING.

The objects of clothing are to protect against cold and against warmth; all other uses will be found to resolve themselves into one or other of these.

The subject naturally divides itself into two parts—1*st*, The materials of clothing; and 2*d*, The make of the garments.

Sub-Section I.—Materials of Clothing.

The following only will be described :—Cotton, linen, jute, wool, leather, and india-rubber.

Cotton—Microscopic Characters.—A diaphanous substance forming fibres about $\frac{1}{1000}$th of an inch in diameter, flattened in shape, and riband-like, with an interior canal which is often obliterated, or may contain some extractive matters, borders a little thickened, the fibres twisted at intervals (about 600 times in an inch). It has been stated that the fresh cotton fibre is a cylindrical hair with thin walls, which collapses and twists as it becomes dry. Iodine stains them brown; iodine and sulphuric acid (in very small quantities) give a blue or violet blue; nitric acid does not destroy them; liquor potassæ dissolves them.

As an Article of Dress.—The fibre of cotton is exceedingly hard, it wears well, does not shrink in washing, is very non-absorbent of water (either into its substance, or between the fibres), and conducts heat rather less rapidly than linen, but much more rapidly than wool.*

* Late experiments have been made on the conducting power of materials by Coulier (Professor of Chemistry at the Val de Grâce), and by Dr Hammond (late Surgeon-General, United

The advantages of cotton are cheapness and durability; its hard non-absorbent fibre places it far below wool as a warm water-absorbing clothing. In the choice of cotton fabrics there is not much to be said; smoothness, evenness of texture, and equality of spinning, are the chief points.

In cotton shirting and calico, cotton is alone used; in merino and other fabrics it is used with wool, in the proportion of 20 to 50 per cent. of wool, the threads being twisted together to form the yarn.

Fig. 87.—Cotton × 285.

Fig. 88.—Linen × 285.

Linen—Microscopic Characters.—The fibres are finer than those of cotton, diaphanous, cylindrical, and presenting little swellings at tolerably regular intervals. The elementary fibres (of which the main fibre is composed) can be often seen in these swellings, and also at the end of broken threads which

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States army). In both cases a polished metallic vessel was filled with hot water of a known temperature, a delicate thermometer inserted, and the vessel was hung in an empty room; the time required for cooling to a given point, when the vessel was uncovered and covered by different fabrics, was noted by the observer at a distance with a magnifying glass.

Coulier's Experiments.
Time required for cooling from 122° Fahr. to 104° Fahr.

	Min.	Sec.
Vessel uncovered, ...	18	12
„ covered with cotton shirting,	11	30
„ „ „ linings,	11	15
„ „ hemp lining,	11	25
„ „ blue woollen cloth for uniforms,	14	45
„ „ red do., for uniforms, .	14	50
„ „ blue do., for greatcoats,	15	5

Hammond's Experiments.
Time required for cooling from 150° Fahr. to 140° Fahr.

	Min.	Sec.
Vessel uncovered, ...	15	11
„ covered with cotton shirting,	9	42
„ „ linen shirting,	7	24
„ „ white flannel,	12	35
„ „ dark blue woollen cloth,	14	5
„ „ light blue woollen cloth,	13	50

have been much used. The hemp fibre is something like this, but much coarser, and at the knots it separates often into a number of smaller fibres. Silk is a little like linen, but finer, and with much fewer knots.

As an Article of Clothing.—Linen conducts heat and absorbs water slightly better than cotton. It is a little smoother than cotton. As an article of clothing it may be classed with it. In choosing linen regard is had to the

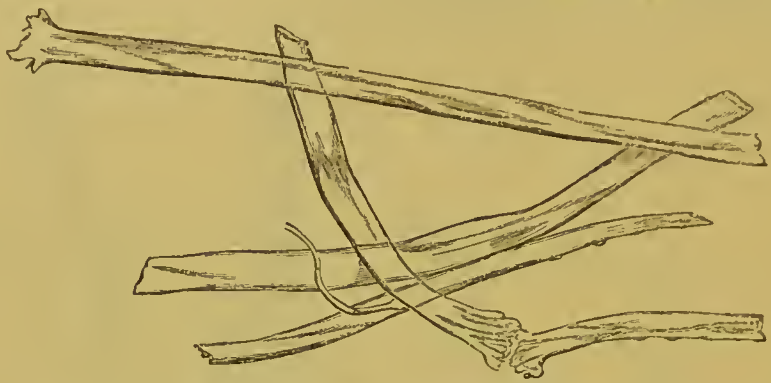

Fig. 89.—Silk × 285. Scale on page 405.

evenness of the threads, and to the fineness and closeness of the texture. The colour should be white, and the surface glossy. Starch is often used to give glossiness. This is detected by iodine, and removed by the first washing.

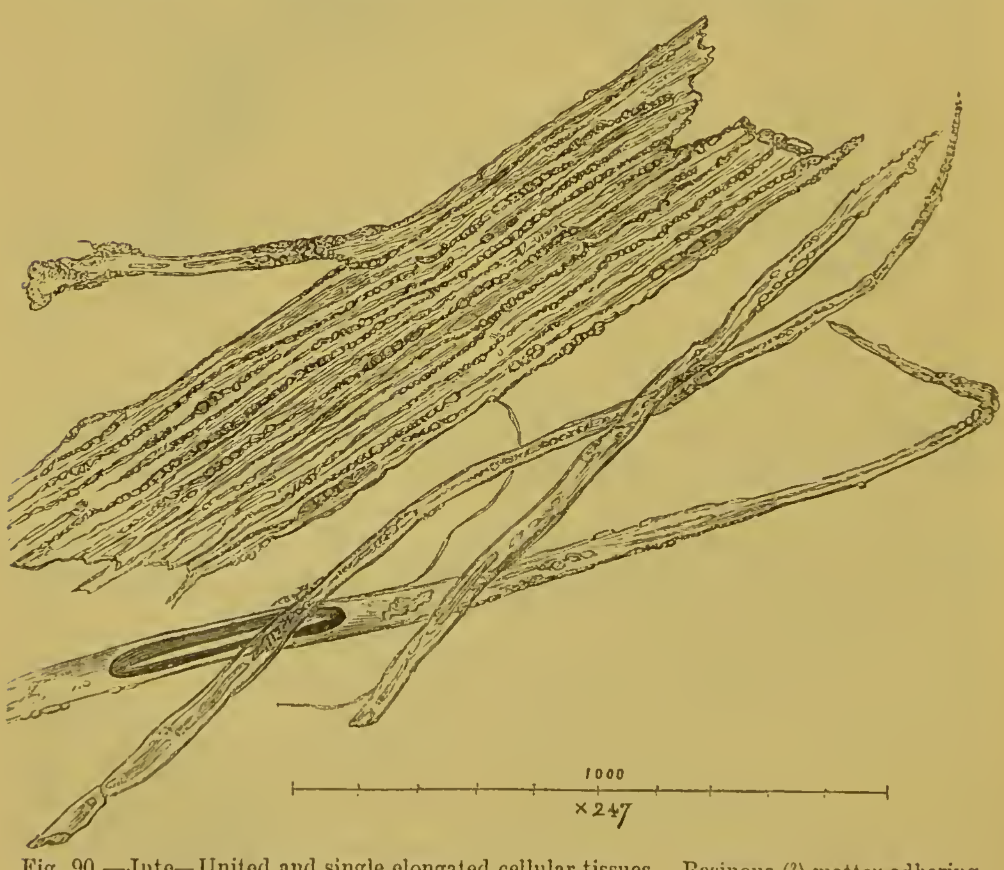

Fig. 90.—Jute—United and single elongated cellular tissues. Resinous (?) matter adhering more or less to all the fibres.

Jute.—As jute is now being very largely used, it is possible it may be

employed as a falsification of linen or cotton. Jute is obtained from the *Corchorus capsularis*, and comes to England from Russia and India. The fibres are of a considerable length, are hollow, thickened, and with narrowings and constrictions in the tubular portions; sometimes an air-bubble may be in the fibre, as shown in the drawing. The drawing, which, as well as the above description, I owe to Dr Maddox, shows the differences between the jute and cotton or linen.

Wool—Microscopic Characters.—Round fibres, transparent or a little hazy, colourless. The fibre is made up of a number of little cornets, which have become united. There are very evident slightly oblique cross markings, which indicate the bases of the cornets; and at these points the fibre is very slightly larger. There are also fine longitudinal markings. There is a canal, but it is often obliterated. When old and worn, the fibre breaks up into fibrillæ; and, at the same time, the slight prominence at the cross markings disappears, and even the markings become indistinct. By these characters old wool can be recognised. Size of fibres varies, but an average is given by the figure. The finest wools have the smallest fibres.

Fig. 91.—Wool × 285.
Scale, $\frac{1}{1000}$th inch.

As an Article of Clothing.—Wool is a bad conductor of heat and a great absorber of water. The water penetrates into the fibres themselves and distends them (hygroscopic water), and also lies between them (water of interposition). In these respects it is greatly superior to either cotton or linen, its power of hygroscopic absorption being at least double in proportion to its weight, and quadruple in proportion to its surface.

This property of hygroscopically absorbing water is a most important one. During perspiration the evaporation from the surface of the body is necessary to reduce the heat which is generated by the exercise. When the exercise is finished, the evaporation still goes on, and, as already noticed, to such an extent as to chill the frame. When dry woollen clothing is put on after exertion, the vapour from the surface of the body is condensed in the wool, and gives out again the large amount of heat which had become latent when the water was vaporised. Therefore a woollen covering, from this cause alone, at once feels warm when used during sweating. In the case of cotton and linen the perspiration passes through them, and evaporates from the external surface without condensation; the loss of heat then continues. These facts make it plain why dry woollen clothes are so useful *after* exertion.*

In addition to this, the texture of wool is warmer, from its bad conducting

* Pettenkofer gives (Zt. für Biol. band i. p. 185) some experiments showing the hygroscopic power of wool as compared with linen. He shows that linen not only absorbs much less water, but parts with it much more quickly; thus, to cite one experiment, equal surfaces of linen and flannel being exposed to the air after being placed in equal conditions of absorption, the linen lost in 75 minutes 5·993 grammes, and the flannel only 4·858 grammes of water. Subsequently the evaporation from the linen lessened, as was to be expected, as it was becoming drier; that from the flannel continued to pass off moderately. The much greater cooling effect of linen is seen.

The porosity of clothing, *i.e.*, the rapidity through which air is driven through is a point to be

power, and it is less easily penetrated by cold winds. The disadvantage of wool is the way in which its soft fibre shrinks in washing, and after a time the fibre becomes smaller, harder, and probably less absorbent.

In the choice of woollen underclothing the touch is a great guide. There should be smoothness and great softness of texture; to the eye the texture should be close; the hairs standing out from the surface of equal length, not long and straggling. The heavier the substance is, in a given bulk, the better. In the case of blankets, the softness, thickness, and closeness of the pile, the closeness of the texture, and the weight of the blanket, are the best guides.

In woollen cloth the rules are the same. When held against the light, the cloth should be of uniform texture, without holes; when folded and suddenly stretched, it should give a clear ringing note; it should be very resistent when stretched with violence; the "tearing power" is the best, perhaps the only way of judging if "shoddy" (old used and worked-up wool and cloth) has been mixed with fresh wool. At the Government Clothing Establishment at Pimlico, a machine is used which marks the exact weight necessary to tear across a piece of cloth. A certain weight must be borne by every piece of cloth.

The dye also must be good, and of the kind named in the contract, and tests must be applied.

Leather.—Choice of leather; it should be well tanned, and without any marks of corrosion, or attacks of insects. The thinner kind should be perfectly supple.

Leather is not only used for shoes, leggings, and accoutrements; it is employed occasionally for coats and trousers. It is an extremely warm clothing, as no wind blows through it, and is therefore well adapted for cold, windy climates. Leather or sheepskin coats are very common in Turkey, Tartary, Persia, the Danubian Provinces, and everywhere where the cold north winds are felt. In Canada, coats of sheepskin or buffalo-hide have been found very useful, and are commonly used for sentries.

India-rubber Clothing.—Like leathern articles, the india-rubber is an exceedingly hot dress, owing to the same causes, viz., impermeability to wind, and condensation and retention of perspiration. It is objected to by many on these grounds, and especially the latter; and Levy informs us that the Council of Health of the French Army have persistently refused (and, in his opinion, very properly) the introduction of waterproof garments into the army. If, however, woollen underthings are worn, the perspiration is sufficiently absorbed by these during the comparatively short time waterproof clothing is worn, and the objection is probably not valid, unless the waterproof is continually worn.

The great use of waterproof is, of course, its protection against rain, and in this respect it is invaluable to the soldier, and should be largely used. By the side of this great use, all its defects appear to me to be minor evils.

India-rubber cloth loses in part its distensibility in very cold countries, and becomes too distensible in the tropics.

General Conclusions.

Protection against Cold.—For equal thicknesses, wool is much superior to either cotton or linen, and should be worn for all underclothing. In case of

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noted. By an equal pressure equivalent to a column of water 4·5 centimetres high, an area of 1 centimetre diameter forced air through as follows:—Through linen, 6·03 litres; flannel, 10·41; lambskin, 6·07; glove-leather, ·15; wash-leather, 5·37; silk fabric, 4·14.

It thus appears that the warmest clothing (flannel) may be the most porous; mere porosity, in fact, is only one element in the consideration.

extreme cold, besides wool, leather or waterproof clothing is useful. Cotton and linen are nearly equal.

Protection against Heat.—Texture has nothing to do with protection from the direct solar rays; this depends entirely on colour. White is the best colour; then grey, yellow, pink, blue, black. In hot countries, therefore, white or light-grey clothing should be chosen.

In the shade, the effect of colour is not marked. The thickness, and the conducting power of the material, are the conditions (especially the former) which influence heat.

Protection against Cold Winds.—For equal thicknesses, leather and india-rubber take the first rank; wool the second; cotton and linen about equal.

Absorption of Perspiration.—Wool has more than double the power of cotton and linen.

Absorption of Odours.—This partly depends on colour; and Stark's observations show that the power of absorption is in this order—black, blue, red, green, yellow, white. As far as texture is concerned, the absorption is in proportion to the hygroscopic absorption, and wool therefore absorbs more than cotton or linen.

Protection against Malaria.—It has been supposed that wearing flannel next the skin lessens the risk of malaria. As it is generally supposed that the poison of malaria enters either by the lungs or stomach, it is difficult to see how protection to the skin can prevent its action; except indirectly, by preventing chill in persons who have already suffered from ague. But the very great authority of Andrew Combe, drawn from experience at Rome, is in favour of its having some influence; and it has been used on the west coast of Africa for this purpose, with apparently good results.

SUB-SECTION II.—MAKE OF GARMENTS.

Special Articles of Soldiers' Clothing.

It will be convenient to divide clothing into two sections—1*st*, Underclothing; 2*d*, Outer clothing. In both cases these articles of clothing must answer their purpose, which is protection from cold or from warmth, without at all interfering with the freest action of muscles or the circulation of the blood, and without pressing on any important part.

1. *Underclothing*, viz., vests, drawers, shirts, stockings, flannel belts, &c.

The soldier, as a rule, wears as underclothing only a shirt and socks. He is obliged to have in his kit two shirts. There has been much discussion as to the respective merits of cotton and flannel shirts. Almost all medical officers prefer the latter, but their cost, weight, difficulty of cleaning, and shrinking in washing, have been objections to its general adoption. Colonel A. Herbert has solved the difficulty by issuing a shirt which is partly wool, partly cotton; it is lighter and cheaper than wool, as durable as cotton, and does not shrink in washing. It is of reddish colour, and of soft even texture. Under the microscope, I counted from 45 to 47 per cent. of wool; the wool is dyed red.

In time of war, shirts may be partially cleaned in this way: The soldier should wear one and carry one; every night he should change; hang up the one he takes off to dry, and in the morning beat it out and shake it thoroughly. In this way much dirt is got rid of. He should then carry this shirt in his pack during the day, and substitute it for the other at night. If in addition great care is taken to have washing parades as often as possible, the difficulty of cleaning would be avoided.

For hot countries, the common English flannels are much too thick and

irritating; flannel must be exceedingly fine, or what is perhaps better, merino hosiery, which contains from 20 to 50 per cent. of cotton,* could be used. The best writers on the hygiene of the tropics (Chevers, Jeffreys, Moore) have all recommended flannel.

The soldier wears no drawers, but in reality it is just as important to cover the legs, thighs, and hips with flannel as the upper part of the body. Drawers folding well over the abdomen form, with the long shirt, a double fold of flannel over that important part, and the necessity of cholera belts or kummerbunds is avoided. Cholera belts are made of flannel, and fold twice over the abdomen.

The soldiers' socks are of cotton; it would be desirable to have them either all of wool, or half cotton half wool; they should be well shrunken before being fitted on. It has been proposed to divide the toes, but this seems an unnecessary refinement. It has been also proposed to do away with stockings altogether, but with the system of wearing shoes, it is difficult to keep the feet perfectly clean. The boots get impregnated with perspiration. Some of the German troops, instead of stockings, fold pieces of calico across the foot when marching; when carefully done, this is comfortable, but not, I believe, really better than a good sock kept clean.

2. *Outer Garments.*—The clothes worn by the different arms of the service, and by different regiments in the same branch, are so numerous and diverse, that it is impossible to describe them. In many cases, taste, or parade, or fantasy simply, has dictated the shape or the material. And diversities of this kind are especially noticeable in times of peace. When war comes with its rude touch, everything which is not useful disappears. What can be easiest borne, what gives the most comfort and the greatest protection, is soon found out. The arts of the tailor and the orders of the martinet are alike disregarded, and men instinctively return to what is at the same time most simple and most useful. It will be admitted that the soldier intended for war should be always dressed as if he were to be called upon the next moment to take the field. Everything should be as simple and effective as possible; utility, comfort, durability, and facility of repair, are the principles which should regulate all else. The dress should not be encumbered by a single ornament, or embarrassed by a single contrivance which has not its use. Elegant it may be, and should be, for the useful does not exclude, indeed often implies, the beautiful, but to the eye of the soldier it can be beautiful only when it is effective.†

Head-Dress.—The head-dress is used for protection against cold, wet, heat, and light. It must be comfortable; as light as is consistent with durability; not press on the head, and not be too close to the hair; it should permit some movement of air over the head, and therefore openings, not admitting rain, must be made, and should present as little surface as possible to the wind, so that in rapid movements it may meet the least amount of resistance. In some cases it must be rendered strong for defence; but the conditions of modern war are rendering this less necessary.

As it is of great importance to reduce all the dress of the soldier to the smallest weight and bulk, it seems desirable to give only one head-dress, instead of two, as at present. Remembering the conditions of his life, his exposure, and his night work, the soldier's head-dress should be adapted for

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* Just before the cotton famine, I got some fine merino hosiery made of a kind suitable for India. I found that, with 40 per cent. of cotton, a fabric could be got of an excellent quality, and within the price of the soldier.

† La tenue, dans laquelle le militaire est prêt à marcher à l'ennemi, est toujours belle. (Vaidy.)

sleeping in as well as for common day-work. Another point was brought into notice by the Crimean war; in all articles of clothing, it much facilitates production, lessens expense, and aids distribution, if the different articles of clothing for an army are as much alike as possible; even for the infantry, it was found difficult to keep up the proper distribution of the different insignia of regiments.

Head-Dress of the Infantry.—The present head-dresses are the bearskin caps for the Guards, busbys for the Foot Artillery and Engineers, the Highland bonnets and shakos for the Line, and forage-caps made of cloth for all.

Nothing can be said in favour of the bearskin. Its shelter from rain is imperfect, it does not protect the eyes from light, it is very hot, it is extremely high, opposes a great surface to the air, and weighs 37 ounces. It is not even an imposing head-dress, because it destroys the idea which should at once arise in looking at the soldier of mixed force and rapidity. In 1854 the embarkation of the Guards for Malta was delayed some days in order that the bearskins might be lowered. It is, however, stated that the Guards were the only regiments who did not throw away their shakos in the Crimea; still there might be other reasons for this, such as the *esprit de corps*, and the chance of paying for the bearskin. The head-dress of the Artillery and Engineers is the busby, neither a showy nor an useful article.

The Scotch bonnets of the Highland regiments are very showy, but no Highlander ever carried the large feather, which destroys the very character of the cap, and renders it heavy and difficult to carry in high winds. The single feather for officers would be much better. The shako of the Infantry of the Line has undergone many changes. Some of the old shakos are most extraordinary; excessively weighty, conical in shape, with the base upwards, so as to be top-heavy. In former years, I have seen men, when at the double, keeping their heads quite stiff to prevent their shakos rolling off, or holding the shakos with their hands. The wind caught shakos of this kind, and the men were obliged to have their chin-straps as tight as possible to keep them on. The Albert hat was an immense improvement; it was lighter, of a good shape, and with a rim behind to prevent the rain from trickling down the back. Men, however, could not sleep in it. Even this shako was so incommodious that the men threw it away in the Crimea, and campaigned in their forage caps.

The present shako is the best that has been issued; it is made of two pieces of waterproof cloth, sewn together by the sewing-machine; its shape is slightly conical; its height is 4 inches in front, $6\frac{1}{2}$ behind; weight, $9\frac{3}{4}$ ounces, including the ball and brass plate, which weigh $1\frac{3}{4}$ ounce. The oil-skin cover weighs in addition $1\frac{1}{2}$ ounce. The peak is horizontal, and measures $2\frac{1}{4}$ inches. There is no rim behind to direct off the rain, but the lower edge of the cap comes well down over the head. Another shako has been partly issued, made of cloth and calico, with a thin sheeting of cork. This weighs only $6\frac{1}{2}$ ounces, but is said to be too expensive for use.

Great as the improvement is over the old dresses, it may be questioned whether another change still may not be desirable, as on all accounts it is important to lessen the weight of the head-dress. Without copying the French kepi or the fez, to which there are many objections, a model of a head-dress is already naturalised among us.

The Glengarry Scotch cap, with a peak and a waterproof falling flap behind, and with ear-flaps, to be put down in case of rain, or in sleeping out at night, has these great advantages. It is very soft and comfortable, presses nowhere on the head, has sufficient height above the hair, and can be ventilated by openings if desired; it cannot be blown off; it can be carried at the top of

the head when desired in hot weather, or pulled down completely over the forehead and ears in cold; with a large flap behind, and ear-flaps, it makes what the soldier wants, a comfortable night-cap, sheltering the back and sides of the neck as well as the head. It is also both an elegant and a national head-dress. Divested of the showy but objectionable feather, which has been foisted in the Highland regiments on the original bonnet, it would be the best head-dress in any army for temperate and subtropical climates. It has now been introduced for forage caps by Colonel Herbert; and there can be no doubt that, if a good waterproof cover with flaps is added for active service, it will be the only head-dress used in war.

The peak of the shako in the English army was worn quite horizontally about thirty-five years ago; it was then made almost vertical, and is now horizontal again. It is perhaps now too horizontal, as it does not shade the eyes at all when the sun is low; a moderate curve would be better.

Head-Dress of the Cavalry.—The Horse Artillery and Cavalry carry helmets and caps of different kinds.

The shape of the helmet in the Guards and heavy dragoons is excellent. It is not top-heavy; offers little surface to the wind; and has sufficient but not excessive height above the head. The material, however, is objectionable. The metal intended for defence makes the helmet very hot and heavy; and the helmet of the Cavalry of the Guard weighs 55 ounces avoir.; that of the Dragoon Guards, 39 ounces (in 1868). But as every ounce of unnecessary weight is additional unnecessary work thrown on the man and his horse, it is very questionable whether more is not lost than is gained by the great weight caused by the metal. Leather is now often substituted in some armies, where the cavalry helmets are being made extremely light.

The Lancer cap weighs 34½ ounces; the Hussar, 29¾ ounces. Both are dresses of fantasy. The Lancer cap, except for its weight, is the better of the two; is more comfortable; shades the eyes; throws off rain better; and offers less resistance to moving air than the Hussar cap.

The undress or forage cap of all corps is a cloth cap, with or without a peak, and varying in shape and kind, according to the regiment, and weighing about 5 ounces.

In Canada, a fur cap is used, with flaps for the ears and sides of the face and neck.

In India many contrivances have been used. Up to the year 1842 little attention seems to have been paid to the head-dress of the infantry, and the men commonly wore their European forage caps. In 1842 Lord Hardinge issued an order, that white cotton covers should be worn over all caps; subsequently, a flap to fall down over the back of the neck was added. The effect of the cotton cover is to reduce the temperature of the air in the hat about 4° to 7° Fahr. Although a great improvement, it is not sufficient.

Afterwards other plans came into use. Pith and bamboo wicker helmets, covered with cotton, have been much used; especially the latter, which are very light, durable, not easily put out of shape, and cheap. The rim should not be horizontal, but inclined, so as to protect from the level rays of the sun. The pith, or "Sola" hats, appear to be decidedly inferior to the wicker helmets; and men have had sun-stroke while wearing them. It seems improbable that anything better than the wicker hat will be devised; but the suggestions which have been made are numerous. It has been proposed to have a bright metallic surface to reflect the heat, but no metal can be provided except aluminium which is light enough, and aluminium is at present much too expensive. A modification of the Chinaman's or Malay's cap has been proposed. In this cap a small flat band passes round the head, and thin

uprights from this support a sort of dome, made of pith or intertwined bamboo, covered with cotton. The sides of the dome come down low enough to shield the eyes and the side of the head. The band does not adhere very firmly to the head, and the cap blows off easily; but the ventilation of the head is excellent. The Malay cap has an exceedingly wide rim, which gives capital shelter, but is not convenient.

The turban has never been much worn in India by the English. It requires some time and care to put on; and if not well arranged, is hotter than the wicker helmet.

In the French infantry the shako is now made of leather and pasteboard, and is divested of all unnecessary ornament, so as to be as light as it can be. It comes well back on the head, being prolonged, as it were, over the occipital protuberance.

In Algeria, the Zouaves, Spahis, and Tirailleurs wear the red fez, covered with a turban of cotton. In Cochin-China, the French have adopted the bamboo wicker helmet of the English.

The natural hair of the head is a very great protection against heat. Various customs prevail in the East. Some nations shave the head, and wear a large turban; others, like the Burmese, wear the hair long, twist it into a knot at the top of the head, and face the sun with scarcely any turban. The Chinaman's tail is a mere mark of conquest. The European in India generally has the hair cut short, on account of cleanliness and dust. A small wet handkerchief, or piece of calico, carried in a cap with good ventilation, may be used with advantage; and especially in a hot land-wind cools the head greatly.

Cravat or Neckcloth.—Few things have given rise to more controversy than the question of the utility of the English soldier's stiff stock. In the days when the stock was at its worst, it was composed of extremely stiff leather, so hard and firm that it was impossible to bend the neck. It rubbed against and irritated the submaxillary glands, and was so uncomfortable that it was months before recruits could wear it with ease. Recruits were sometimes made to sleep in it, in order to accustom them to it more quickly. Of late years the stock has been made lower, and more flexible; and this modified stock is still worn in England, though it is now quite discarded in India, where a thin handkerchief takes its place.

It certainly seems wonderful that an apparatus of this kind should have found defenders; for it was not merely uncomfortable, and somewhat impeded the return of blood through the external jugulars, and hindered the action of some of the accessory muscles of respiration, but also (what would be more perceptible to soldiers) rendered impossible the bending and varying attitudes of the neck, which occur when a man makes a strong exertion. For great exertion with the upper extremities cannot be made if the clavicles and scapula are not rigidly fixed; and they cannot be fixed unless the neck can easily bend. On every account, physiological and mechanical, the neck should be left as bare as possible. Nor is there any medical reason why it should not be. Like the face, the neck soon gets accustomed to exposure; and besides, if we let Nature follow her own course, there is the beard to shelter important parts. Among many work-people exposed to vicissitudes of weather, among English sailors and the French Zouaves, the neck is left quite bare without injury. A stock may, indeed, turn a half-spent rifle ball; but clothes are not to be considered a defence; and even if they were, where are we to stop in our application of such a principle? In time of war, also, the stock is at once thrown away. In the Crimea, the stock and the shako were at once discarded.

If the neck is covered at all, it should be with a very thin and supple cloth. The collar of the coat should be made low and loose, so as to give full freedom to every movement of the neck, and not to compress the root of the neck in the slightest degree.*

In Algeria the French troops have long worn a thin cravat of cotton; and a decree of March 1860 extended its use to all the corps of infantry.

Coat, Tunic, Shell-Jacket, &c.—The varieties of the coat are very numerous in the army; and there are undress and stable suits of different kinds. The infantry now wear the tunic, which is a great improvement over the old cut-away coatee. It is still, however, too tight, and made too scanty over the hips and across the abdomen. A good tunic should have a low collar, and be loose round the neck, over the shoulders (so as to allow the deltoid and latissimus the most unrestricted play),† and across the chest. It should come well across the abdomen, so as to guard it completely from cold and rain; descending loosely over the hips, it should fall as low over the thighs as is consistent with kneeling in rifle practice, *i.e.*, as low as it can fall without touching the ground. Looking not only to the comfort of the soldier, but to the work and force required of him, it is a great mistake to have the tunic otherwise than exceedingly loose. A loose tunic, a blouse in fact, is in reality a more soldier-like dress than the tight garment, which every one sees must press upon and hinder the rapid action of muscles. The tunic should be well provided with pockets, not only behind, but on the sides and in front; the pockets being internal, and made of a very strong lining. In time of war, a soldier has many things to carry; food, extra ammunition sometimes, all sorts of little comforts, which pack away easily in pockets. If the appearance is objected to, they need not be used in time of peace; but with a loose dress, they would not be seen.

The colour of the tunic is red in most regiments. It is a very striking colour, but it soils easily; and as it appears to be more easily seen at a distance than other colours, there can be little doubt that the inexorable necessities of war will soon cause the "red coats" of England to be merely historical.

A great improvement has been lately made by Colonel Herbert. The old shell-jacket is done away, and a loose frock substituted. As this is sure to become the working dress, and the tunic will be kept for parades merely, the soldier will have the great advantage of a loose dress.

In India the tunic is made loose, and of thin material.

Waistcoats.—No waistcoats are worn in the British army, but they ought to be introduced. A long waistcoat with arms is one of the most useful of garments; it can be used without the tunic when the men are in barracks or on common drill. Put on under the tunic, it is one of the best protections against cold. At present the men are obliged to wear tight coats, and having nothing under them, line them with flannel and wadding. In winter and summer they often wear the same dress, although the oppression in the summer is very great. If the tunic were made very loose of some light material, and if a good short Jersey or Guernsey frock were allowed to be worn at the option of the men, the men would have cool dresses in summer, warm in winter, and the thin tunic would be more comfortable in the Mediterranean and sub-tropical stations.

Trousers.—Formerly the army wore breeches and leggings; but shortly

* Mr Myers, of the Coldstream Guards, has lately (Lancet, Feb. 1869) directed attention to this and other points connected with the stiff dress, especially with the tight tunic and collar. He even thinks the present stock worse than the old very stiff high one, which, if it pressed on the chin, was so stiff that it was loose about the neck.

† This cannot occur if epaulets are worn; and it is to be hoped nothing will ever occur to bring in again the use of the so-called ornaments.

before or during the Peninsular war trousers were introduced. The increased comfort to the soldier is said to have been remarkable; the trouser, indeed, protecting the leg quite down to the ankle, seems to be as good a dress as can be devised, if it is made on proper principles, viz., very loose over the hips and knees, and gathered in at the ankle, so that merely sufficient opening is left to pass the foot through. The much-laughed-at pegtop trousers seem to be, in fact, the proper shape. In this way the whole leg is protected, and the increased weight given by the part of the trousers below the knee is a matter of no consequence.

In the French Army the trousers are now made large at the ankle, so as to be turned up inside during marches; a fastening is placed inside the trousers below the knee, and the trousers then falling from this reach to mid-leg.

The "knickerbockers" differ from this, as they cannot be let down. It has been proposed to introduce them into the army, and they are actually in use in some volunteer regiments. But though very easy, and adapted for gentlemen while shooting, they do not seem to me fitted for the soldier. Leggings constantly worn are necessary, or the leg is left bare. Now, the soldier requires a garment which may constantly cover him, and the rather heavy leggings are not adapted for this. It is also introducing two garments where one would do, and therefore increase the complexity of the dress, and lessening the rapidity of dressing. Besides, what is gained by this, if the trousers are made equally loose about the hips and knees and calves? It is here that the impediment to free movement exists. The trousers at present are made so tight over the hips that to overcome their resistance some force is lost every time the muscles act.

The trousers are supported either by braces or a belt. If the latter be used, it should be part of the trousers, should fit just over the hip, and not go round the waist. It must be tight, and has one disadvantage, which is, that in great exertion the perspiration flowing down from above collects there, as the tight belt hinders its descent. Also, if heavy articles are carried in the pocket the weight may be too great for the belt. Braces seem, on the whole, the best.

Trousers should be made with large pockets, on the principle of giving the men as much convenience as possible of carrying articles in time of war.

In India, trousers are made in the same fashion as at home, but of drill or khakee cloth, or thin serge—an excellent material especially for the northern stations.

Leggings and Gaiters.—Formerly long leggings reaching over the knees, and made of half-tanned leather, were used. They appear not to have been considered comfortable, and were discarded about fifty years ago. Short gaiters were subsequently used for some time, but were finally given up, and for several years nothing of the kind was worn. After the Crimean war Lord Herbert introduced for the infantry short leather leggings, 6 inches in height, and buttoning on the outside. These are now being superseded by leggings which come up to the knee, and are much more serviceable.

In some of the French regiments a gaiter of half-dressed hide comes up to just below the knee; short calico or linen gaiters are worn by other corps; a flap comes forward over the instep.

The calico gaiters have been much praised, but they soon get saturated with perspiration, thickened in ridges, and sometimes irritate the skin. On the other hand, leather gaiters, if not made of good leather, lose their suppleness, and press on the ankles and instep.

A great advantage of gaiters and leggings is that at the end of a march they

can be at once removed and cleaned; but, on the whole, if suitable leather could be fixed to the bottom of trousers, it seems to me they might be abandoned.

Shoes and Boots.—In the action of walking the foot expands in length and breadth; in length often as much as $\frac{1}{10}$th, in breadth even more. In choosing shoes this must be attended to. The shoemaker measures when the person is sitting, and as a rule allows only $\frac{1}{24}$th increase for walking. Ankle boots, weighing 40 to 42 ounces, are now worn by the infantry; the cavalry have Wellingtons and jackboots. The jackboots of the Life Guards weigh (with spurs) 100 ounces avoir. Shoes cannot be worn without gaiters. Ankle boots are preferable; in the English army they are now made to lace, and are fitted with a good tongue. Great attention is now paid at Pimlico to the shape and make of the boot,* and the principles laid down by Camper, Meyer, and others, are carefully attended to. There are eight sizes of length and four of breadth, making thirty-two sizes in all. The boots are made right and left. The heel is made very low and broad, so that the weight is not thrown on the toes, the gastroenemii and solei can act, which they cannot do well with a high heel, and there is a good base for the column which forms the line from the centre of gravity, and the centre of gravity is kept low; the inner line of the boot is made straight, so as not to push outwards the great toe in the least degree, and there is a bulging over the root of the great toe to allow easy play for that large joint. Across the tread and toes the foot is made very broad, so that the lateral expansion may not be impeded; the toes are broad. Great care is taken in the inspection of the boots, the order of inspection being—1*st*, The proof of the size, which is done by standard measure; 2*d*, The excellence of the leather, which is judged of by inspection of each boot, and by selecting a certain number from each lot furnished by a contractor, and cutting them up; if anything wrong is found, the whole lot is rejected; 3*d*, The goodness of the sewing; there must be a certain number of stitches per inch (not less than eight for the upper leathers), a certain thickness of thread, and the thread must be well waxed. The giving up of boots is generally owing to the shoemaker using a large awl, and thin unwaxed thread, with as few stitches as possible; the work is thus easier to him, but the thread soon rots.

Sometimes boots are not sewn, but pegged, but there seems to be some difficulty in repairing them on service, and after some trial they have been given up in the English service.

Some other plans have been proposed. Mr Dowie† has introduced an elastic, instead of the rigid "waist." This bends easily with the foot, and thus all the muscular effort necessary for overcoming the resistance of the rigid waist is gained for progression. A similar object is sought for in the "Hythe boot" of Colonel Carter, who has introduced a slit across the tread, which permits enough movement to give increased facility in walking, and especially in going up hills, and to render some of the attitudes in rifle prac-

* The importance of a good boot is known to every soldier. Marshal Saxe says in his "Memoirs" that there is no article of the soldier's dress more important, and that battles are won by legs. Sir John Burgoyne, in his interesting paper on Dress ("Professional Papers of the Royal Engineers," 1863, p. 121), tells an anecdote of the Duke of Wellington. On being asked what was the best requisite for a soldier, the Duke replied, "A good pair of shoes!" What next? "A spare pair of good shoes!" What next? "A spare pair of soles!"

† Mr Dowie is a boot and shoe maker in the Strand. He has the credit of writing a very sensible work on the "Foot and its Covering" some years ago, in which he incorporated Camper's well-known and philosophical treatise on the Foot. To Mr Dowie must certainly be given the credit of having again directed attention to this point. Other works have lately been published, "Why the Shoe Pinches," a translation of Dr Meyer's work by Dr Craig, and an excellent work on the "Foot and Hand" by Mr Humphry of Cambridge.

tice more easy. Some shoemakers now put two or three slits in the sole, filling them up with vulcanised india-rubber. Others have used a thin elastic steel band in the "waist."

Considering the great injury inflicted on the foot by tight and ill-made boots, by which the toes are often distorted and made to override, and the great toe is even dislocated and anchylosed, it is plain that the increased attention lately excited on this point is not unnecessary. The compression of children's feet by the tight leather shoes now made is extremely cruel and injurious.

It may, indeed, be asserted that the child's foot would be better if left altogether unclothed, and certainly we see no feet so well modelled as the children of the poor, who run about shoeless. In the case of the soldier, too, who has in many campaigns been left shoeless, and has greatly suffered therefrom,* it is a question whether he should not be trained to go barefooted.† The feet soon get hard and callous to blows, and cleanliness is really promoted by having the feet uncovered, and by the frequent washings the practice renders necessary. After being unworn for some time, shoes that previously fitted will be found too small, on account of the greater expansion and growth of the foot, and this is itself a strong argument against the shoe as commonly worn.

The sandal in all hot countries is much better than the shoe, and there is no reason why it should not be used in India for the English soldiers as it is by the native; the foot is cooler, and will be more frequently washed. For all native troops, negroes, &c., the sandal should be used, and the boot altogether avoided. In campaigns it is most important to have large stores of boots at various points, so that fresh boots may be frequently issued and worn ones sent back for repair. Soldiers ought to be trained to repair their own boots.‡

Greatcoat and Cloak.—In the cavalry, cloaks, with capes which can be detached, are carried. They are large, so as to cover a good deal of the horse, and are made of good cloth; the weight is about 5 ℔ to 6 ℔ for the cloak, and 2½ ℔ to 3 ℔ for the cape. The infantry wear greatcoats weighing from 5 ℔ to 6 ℔. They are now made of extremely good cloth, are double-breasted, and are as long as can be managed. They are not provided with pockets at the back, which is a serious omission, and they also should have loops, so that the flaps may be turned back if desired. They are too heavy, and absorb a great deal of wet, so that they dry slowly. General Eyre's Committee on Equipments has lately recommended a light greatcoat, and in addition a good waterproof cape. The suggestion seems to be a very good one. A hood might also be added with advantage. In countries with cold winds they are a great comfort.

The greatcoat is perhaps the most important article of dress for the soldier. With a good greatcoat, Robert Jackson thought it might be possible to do

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* We all know how frequently this subject is referred to in the Duke of Wellington's despatches. In the Indian mutiny several regiments were shoeless, and the 84th Regiment, in its rapid pursuit after Koer Singh, suffered greatly from this cause.

† Mr Dowie states that at the battle of Maida the Highlanders, when ordered to charge, stopped to pull off their boots, and then, freed from these incumbrances, made that famous onset which rendered the first meeting in that war of the French and British soldiers so celebrated.

‡ It may be worth while to give a receipt for making boots impermeable to wet. I have tried the following, and found it effectual:—Take half a pound of shoemaker's dubbing, half a pint of linseed oil, half a pint of solution of india-rubber (price 2s. per gallon). Dissolve with gentle heat (it is very inflammable), and rub on the boots. This will last for five or six months; but it is well to renew it every three months. At a small expense the boots of a whole regiment could be thus made impermeable to wet.

away with the blanket in war, and if india-rubber sheets were used this is perhaps possible. In the Italian war of 1859, the French troops left their tunics at home, and campaigned in their greatcoats, which were worn open on the march.*

In countries liable to great vicissitudes of temperature, and to sudden cold winds, as the hilly parts of Greece, Turkey, Affghanistan, &c., a loose, warm cloak, which can be worn open or folded, is used by the inhabitants, and should be imitated in campaigns. It is worthy of remark, that in most of these countries, though the sun may be extremely hot, the clothes are very warm.

In very cold countries, sheepskin and buffalo-hide coats, especially the former, are very useful. No wind can blow through them; in the coldest night of their rigorous winter the Anatolian shepherds lie out in their sheepskin coat and hood without injury, though unprotected men are frozen to death. In Bulgaria, the Crimea, and other countries exposed to the pitiless winds from Siberia, and the steppes of Tartary, nothing can be better than coats like these.

* Cloth may be made waterproof by the following simple plan:—Make a weak solution of glue, and while it is hot add alum in the proportion of one ounce to two quarts; as soon as the alum is dissolved, and while the solution is hot, brush it well over the surface of the cloth and then dry. It is said that the addition of two drachms of sulphate of copper is an improvement. Sometimes native products in India will make cloth waterproof. This is the case with the wood oil, or Thietsie of Burmah. When I was serving in Burmah I made many experiments with this curious substance, and found that common American drill could be made quite waterproof with it.

Poisonous Dyes.—The use of dyes (especially red dyes) which are extremely irritating to the skin, has lately attracted much attention. M. Tardieu has published some observations on this point, which have been noticed by the British Medical Journal (March 6, 1869). Tardieu states that there are six organic red dyes, viz.—1. Madder (garancine) which is not altered by a solution of 3 or 4 per cent. of ammonia or hydrochloric acid. 2. Cochineal, which is turned violet by ammonia, and gives a bright violet colour to the ammoniacal liquid. 3. Murexide, which is bleached by citric acid. 4. Carthamine (a red colouring matter from safflower) is decolorised by boiling with a weak solution of soap (1 part of soap in 200 of water). 5. Magenta (aniline-red) is decolorised by ammonia. 6. Coralline is not lessened in intensity by alkaline fluids, but boiling alcohol dissolves it, and the colour of the solution is intensified by ammonia or potash, a character which distinguishes it from magenta. Mr Wanklyn has pointed out (ibid.) that magenta often contains arsenic, and that at present a composite dye of magenta and some orange colouring matter is used and is doubly poisonous, both from arsenic and the irritant orange dye. Of the above, coralline and magenta with arsenic appear to be the worst. The above tests will be useful in enabling these dyes to be identified.

CHAPTER XV.

WEIGHTS OF THE ARTICLES OF DRESS AND OF THE ACCOUTREMENTS, AND ON THE MODES OF CARRYING THE WEIGHTS.

SECTION I.

WEIGHTS.

THE following tables give the weights of all the articles used by a Heavy Cavalry Regiment, an Hussar Regiment,* and the Infantry of the Line. The weights carried by the Artillery are much the same as those of the Cavalry. The weights of the helmets and jackboots of the Life and Horse Guards have been already mentioned. The cuirass weighs 10 ℔ 12 oz.; it rests a little on the sacrum and hip, and in that way is more easily borne by the man. With these exceptions, the weights may be considered nearly the same as those of the heavy dragoons.

CAVALRY.

The weight of the accoutrements and equipment is in great part carried by the horse. The cloak, when not worn, is carried in a roll over the shoulder, or sometimes round the neck, or in front on the horse.

Weights of Dress, Equipments, Arms, and Horse Appointments of the Private Soldier in the 5th Dragoon Guards (1869).

Articles.	℔	oz.
CLOTHING.		
Helmet and Plume,	2	7
Tunic,	2	14
Leather overalls,	3	7
Boots and spurs,	3	12
Gauntlets,	1	0
Shirt,	0	13½
Socks,	0	4½
Cloak,	8	10
Cape,	2	10½
SADDLERY.		
Saddle-tree, seat, flaps, and girth,	13	5½
1 Pair pannels,	5	4½
Stirrup-iron and leathers,	2	11½
Crupper,	0	14¼
Breastplate and strap,	1	5
Carry forward,	49	7¼

Articles.	℔	oz.
Brought forward,	49	7¼
Surcingle,	0	15¾
Baggage straps,	0	8½
Wallets, packed and strap,	9	4
Cloak-strap,	0	2
1 Pair of horse shoes and cases, packed,	3	9
1 Pair horse-shoe straps,	0	4½
Carbine buckle-strap,	2	5¼
Bridle,	2	13½
Bridoon and reins,	1	4½
Head-collar,	1	10
Collar-chain,	1	12¾
Horse-log,	1	3½
HORSE APPOINTMENTS.		
Shabraque,	4	8¼
Sheepskin,	5	0½
Carry forward,	84	13¼

* For this account I have to thank Surgeon-Major Dr Fyffe and Dr Fraser, 10th Hussars.

Weight of Dress, Equipments, &c., 5th Dragoon Guards—continued.

Articles.	lb	oz.
Brought forward,	84	13¼
Numnah, . . .	2	14½
Valise, packed in service marching order, . .	16	0½
Corn-sack, . . .	1	12¼
Corn-bag, . . .	1	7¼
ARMS AND ACCOUTREMENTS.		
Mess-tin and strap, .	1	5
Cloak, ...	11	4½
Carbine, . . .	7	2½
Carry forward,	126	11¾

Articles.	lb	oz.
Brought forward,	126	11¾
Sword blade, . . .	2	7¾
Sword scabbard, . .	2	1
Waist-belt and carriages,	0	15
Sword-billet, . . .	0	3¾
Sword-knob, . . .	0	2½
Pouch and 10 rounds ammunition, . . .	1	11¼
Pouch-belt, . . .	0	11¼
Haversack, . . .	0	10¾
Water-bottle and strap, .	1	11¾
	137	6¾

Weight of Men's Clothes, Necessaries, &c., 10th Royal Hussars (1869).

No.	Articles.	lb	oz.
1	Tunic, . . .	3	0
1	Busby, plume, and lines,	1	13¾
1	Pair leather overalls and straps, . . .	3	6
1	Pair cloth do. do., .	2	7½
1	Stable-jacket, . .	1	15½
1	Forage-cap, . .	0	5
1	Valise, . . .	2	7
1	Cloak, 5 lb. 8½ oz.; cape, 2 lb 6 oz., . .	7	14½
1	Pair boots, . . .	3	0¼
1	„ spurs, . . .	0	5¼
1	„ highlows, . .	3	8
1	Stable-bag, . . .	0	6
1	Pair braces, . .	0	3¾
1	Button-brush, . .	0	1½
1	Cloth „ . . .	0	3½
1	Hair „ . . .	0	2¾
1	Brass „ . . .	0	2¾
1	Lace „ . . .	0	1
1	Shaving „ . . .	0	1¼
2	Shoe „ . . .	0	7½
1	Tin blacking, . .	0	4½
	Carry forward,	32	5¼

No.	Articles.	lb	oz.
	Brought forward,	32	5¼
1	Hair-comb, . .	0	0½
2	Pairs drawers, each 13¾ oz., ...	1	11½
2	Pairs gloves, each 7¼ oz	0	14½
Or 4	„ cotton socks, each 2¼ oz. . .	0	9
1	Brass paste, . .	0	3½
1	Hold-all, . . .	0	4
1	Horse-rubber, . .	0	11
1	Knife, fork, and spoon,	0	4½
1	Pipe-clay and sponge,	0	2
1	Razor, . . .	0	2½
3	Shirts, each 14½ oz., .	2	11½
1	Button brass, . .	0	1¾
1	Stock, . . .	0	1½
2	Towels, 7¾ oz. each, .	0	15½
1	Stable trousers, .	1	5
2	Flannel jackets, each 11 oz.	1	6
1	Oil tin, . . .	0	2¼
1	Pair foot-straps, .	0	0½
1	Mess-tin and strap, .	1	1½
1	Account-book, . .	0	1½
		45	3½

Weight of Saddlery, 10th Royal Hussars.

No.	Articles.	lb	oz.
	Saddle-tree, . . .	6	5½
	„ seat, . . .	1	6½
	Pair flaps, . . .	2	8½
	„ pannels, . . .	4	6½
	Girth-tub, . . .	0	6½
	Girth-leather, . .	1	1½
	Stirrup-irons, . .	1	11½
	„ leathers, . .	1	3½
	Crupper, . . .	0	14½
	Breastplate, . . .	1	4¼
	Carry forward,	21	4¾

No.	Articles.	lb	oz.
	Brought forward,	21	4¾
	Surcingle, . . .	0	15
	Set of baggage-straps, .	0	9¼
	„ cloak-straps, .	0	9½
	Pair wallets, . . .	1	14½
	Pair shoe-cases and straps,	1	4
4	Horse shoes and nails,	4	9
	New carbine bucket, .	2	13½
	Bridle-bit and head-stall,	2	2
	Bridoon-bit and reins, .	1	2
	Carry forward,	37	3½

Weight of Saddlery, 10th Hussars—continued.

No.	Articles.	lb	oz.
	Brought forward,	37	3½
	Curb-chain,	0	3¾
	Bit-reins,	0	10½
	Head-collar,	1	11½
	Collar-chain,	1	12½
	Sheepskin,	4	4
	Shabraque,	4	6½
	Numnah,	2	11¼
	Corn-sack,	1	11½
	Nose-bag,	1	1½
	Horse-brush,	0	11
	Curry-comb,	0	11
	Sponge,	0	2
	Hoof-picker,	0	1¾
	Scissors,	0	3½
	Horse-log,	1	3¼
	Carry forward,	58	13

No.	Articles.	lb	oz.
	Brought forward,	58	13
	Haversack,	0	9
	Carbine,	6	9
	Pouch-belt, 11¼ oz., Pouch, 12½ oz., 20 Rounds ammunition, 32½ oz.,	3	8¼
	Waist-belt, &c., 1 lb. 1 oz., Sabretash and slings, 1 lb. 5½ oz., Sword, 4 lb. 10 oz.,	7	0½
		76	7¾
	Weight of equipments,	121	11¼
	Total weight of Hussar* with all his equipments,	259	6¼

Infantry.

The articles of the infantry soldiers' kit have been already noted. The kit is divided into the service and the surplus kit, the latter being always carried for, and not by, the man. The service kit consists of the clothes he wears, and of some duplicate articles and other necessaries.

These articles consist of one shirt (12 ounces in weight), pair of socks (4 oz.), pair of trousers (23 or 32 oz. according to kind), pair of boots (42 oz.), towel (8 oz.), hold-all, and knife, fork, and spoon (2½ oz.), two brushes (6 oz.), tin of blacking (6½ oz.), forage cap (4 oz.)

It is not possible to state accurately the weights of all the articles of kit and equipment, as some are now being altered, but the following table is fairly correct :—

	Average weight in lbs. and ounces. lbs.	oz.
Weight of clothes on person (including shako, winter trousers, and leggings),	10	0
Personal necessaries, viz., service kit in valise,	6	12
Greatcoat,	5	8
Valise equipment for carrying necessaries, greatcoat and armament, viz., valise, two pouches, ball-bag, suspenders, waist-belt, frog, coat-straps,	4	8
Haversack,	0	8
Canteen,	1	9
Armament, viz., rifle and sling (9 lb 8 oz.), bayonet (1 lb), ammunition (60 rounds, 6 lb weight = 1 lb for 10 rounds nearly),	16	8
Field necessaries, viz., water-bottle—water, 1 pint (16 oz.), blanket (4 lb), provisions for 3 days (6 lb),	11	0
	56	5

* Average weight of men of 10th Hussars (1869) = 137 lb. 11 oz.*; average height, 5 feet, 7¼ inches.

* By an oversight in the last edition, the weight of the men was given with, instead of without, the clothes.

The total weight thus carried would of course be much less in peace. By omitting the field necessaries, 40 rounds of ammunition and one pouch, the weight of the peace equipment is lessened to 41 lb, and if the canteen were only carried when it was wanted, the weight would be under 40 lbs. If the greatcoat with the cape could be reduced to 5 lb, and the summer trousers and the boots were left out of the valise, the weight would be reduced below 36 lb, and still the soldier would have really everything necessary for his comfort.

Some experienced officers, however, consider it essential that the second pair of boots should be always carried by the soldier. No doubt a man should have a second pair of boots, and there may be circumstances in periods of peace when he might desire to have them with him; but surely there is no necessity for him to carry, as he does now, even if he only goes on guard on a fine day, a pair of boots which he never puts on. It might be left to his discretion to carry his extra boots, and it is pretty certain he will take them when they add to his comfort. So also with the second pair of trousers; why should they be constantly carried when they are scarcely ever wanted? There should be the means of carrying these articles when they will be actually wanted, but the man should not be weighted with them on all possible occasions.

In time of war it is most important to have the soldier as little weighted as possible. The long and rapid marches which have so often decided wars have never been made by heavily laden men. The health also suffers. It is of national importance that the soldier should be as healthy and as efficient as possible, as the fate of a nation may be staked on the prowess of its army. The line which the weight of his necessaries should not exceed should be drawn with the utmost care; if his health suffers more by carrying some extra pounds of weight than it benefits by the comfort the articles give, why load him to his certain loss? The overdoing the necessaries of the soldier has always been a fault in our army; Robert Jackson noticed it seventy years ago. "It is a mistake," he says, "to multiply the equipment of the soldier with a view of adding to his comfort."

There are certain articles of material comfort to a man on service in a cold or wet country, and I believe some alteration in the present arrangement would be desirable. I venture to propose, therefore, some slight changes. The greatcoat, blanket, and a waterproof sheet (or portion of a shelter tent), to keep both the coat and blanket and the man himself dry, are articles of the utmost importance; there is scarcely anything that a soldier might not dispense with sooner than these. But their weight is considerable, and it is necessary to sacrifice something else to secure them. The second pair of trousers is clearly unnecessary, and if he started with a thoroughly good pair of boots made waterproof, as can be easily done, and had a cheap loose shoe which he might put on after a fatiguing march, and if a proper transport were provided for due renewal, the second pair of boots might be left out. A spare shirt, towel, socks, brushes (or better still, a small tooth-comb for the hair, which prevents vermin), a small hold-all, and a clasp-knife and spoon, would comprise all that would be necessary, in addition to his haversack, water-bottle, and provisions. The forage cap with waterproof cover should be substituted for the shako.

If such a plan were followed the weight of such a war equipment would be as follows:—

	lb. avoir.	oz.
Clothes on person,	10	0
Service kit in valise, viz., shirt (12 oz.), towel (8 oz.), soap (2 oz.), 1 brush (3 oz.), hold-all (3 oz.), socks (4 oz.), shoes (16 oz.),	3	0
Greatcoat,	4	0
Waterproof sheet (with appliances for tentage),	5	0
Blanket,	4	0
Haversack and three days' provisions,	6	0
Water-bottle and 20 fl. oz. of water,	1	8
Canteen,	1	8
Valise equipment,	4	8
Armament,	16	8
	56	

This would be the same weight as before, with a waterproof sheet added. On ordinary occasions in war, as he would only carry one day's provisions and 40 rounds of ammunition, the weight would only be 52 lb. While he would be more comfortably provided, he would be less weighted than with the present system, and would be able, if it were required, to carry entrenching tools.

The valise equipment proposed by General Eyre's Committee, and which has been now adopted for the army, possesses great facilities for carrying these articles, as will be presently noticed.

This committee have also recommended that, instead of the squad-bag for 25 men, each man shall have a separate canvas bag for his surplus kit, as is now provided on board ship. In time of peace this would be carried for him, as the squad-bag is at present; in time of war it would be left at home.

It is of great moment to give each man a bag for surplus kit to himself. It encourages the men to take care of their things, and enables them to pack them comfortably. The men of the Army Hospital Corps who have such bags have told me that they find these bags in all respects preferable to the squad-bags.

It may be interesting to give the weights of the various articles carried by the infantry soldier of the French, Prussian, and Russian armies.

*Equipment of the French Infantry Soldier (in 1867).**

Articles.	Weight. English Measure. lb avoir. and 10ths of a lb.	
CLOTHING.		
1 Greatcoat,	4·73	
2 Tunics,	3·08	each
1 Pair trousers,	1·58	
1 Cap (night),	·484	
1 Shako,	1·46	
Epaulettes,	·264	
1 Bag,	1·98	
EQUIPMENT.		
Pouch,	1·914	
Pouch-belt,	·814	
Gun-strap,	·176	
Carry forward,	16·842	

Articles.	Weight. English Measure. lb avoir. and 10ths of a lb.
Brought forward,	16·482
ARMAMENT.	
1 Gun and bayonet (the fusil chassepot weighs 4·5 kil.),	10·08
Sword,	2·93
Case for arms,	·22
"Monte-ressort,"	·232
Bayonet sheath,	·11
Hache de campement,	2·2
2 Packets of 15 cartridges each,	3·19
Carry forward,	35·444

* Rossignol, "Hygiène Pub.;" and Boudin, p. 266. The weights have been corrected to present date by an officer in the French army.

Equipment of the French Infantry Soldier—continued.

Articles.	Weight. English Measure. lb avoir. and 10ths of a lb.
NECESSARIES.	
Brought forward,	35·444
3 Shirts, 550 grammes each,	3·6300
2 Collars, 30 grammes, .	·1320
1 Pair linen gaiters, .	·8360
2 Pairs shoes, 690 grammes,	3·0360
1 Pair drawers, . .	·9680
2 Pairs gloves, 25 grammes,	·1100
2 Caps, 45 do.,	·1980
1 Memorandum book, .	·0660
1 Tunic case, ...	·2640
1 Pompon, . . .	·1100
Carry forward,	44·7940

Articles.	Weight. English Measure. lb avoir. and 10ths of a lb.
NECESSARIES.	
Brought forward,	44·7940
1 Musette, . . .	·3080
1 Fusil stop, . . .	·0440
1 Pair braces, . .	·1980
1 Pair buckles, . .	·0264
1 Haversack, . . .	2·4926
1 Large strap, . .	·2640
2 Small round planchettes for tunic case, . .	·2200
1 Tin bowl, iron spoon, pocket-knife, and fork,	·6050
Total,	48·9520

To this weight must be added :—

	lb
Pack, ...	4·73
Blanket, ...	3·5
Share of *tente d'abri* and supports, ...	4
Water-bottle and water, ...	2
Rations for three days,*	6
	20·23
Grand total, ...	69·182

Prussian Infantry Soldier (1869).

Articles.	English Weight. lb	oz.
Tunic, ...	3	12
Boots (1 pair on, 1 pair in knapsack = 3·80 each)	6	15·46
Cloth trousers, . .	3	5·8
Greatcoat or cloak, .	5	7
Ball cartridges—80 rounds,	7	3·728
Shirt (1 on, 1 in knapsack),	1	13·36
Linen trousers, . .	1	5·88
Ear covers, ...	...	·88
Stock (stiff necktie), .	...	1·32
Gloves, ...	...	4·70
Knapsack (empty) with straps,† . . .	5	12·93
Belt with 2 pouches (empty), . . .	2	6·7
Mess tin, ...	2	·2
2 Tin cases for more cartrides, . . .	...	9·85
Grease box (empty in knapsack), . .	...	·98
Linen for feet in knapsack,	...	9·7
Do. in wear,	...	9·3
Carry forward,	42	7·788

Articles.	English Weight. lb	oz.
Brought forward,	42	7·788
Linen (rolled bandage) for dressing wounds, .	...	1·6
Bag for rice, . .	...	·5
Bag for salt, . .	...	·35
Housewife (needle and thread), . . .	...	4·75
Prayer-book, . .	...	2·82
Brush for clothes, .	...	4·23
Haversack (bag for bread),	...	5·29
Soles, 1 pair in knapsack,	...	7·1
Leather, cut for heels, 1 pair, . . .	...	1·6
Forage cap, ...	...	5·2
Box, with duplicate parts of the rifle, . .	...	1·76
Sidearm with scabbard,	2	3·89
Helmet, ...	1	14·87
Rifle, ...	11	10·1
Sword without scabbard,	1	12·22
Water bottle (empty),	...	14·11
	63	2·178

* The French soldier, however, often carries as much as 13 lb weight of rations.—Rossignol, *Hygiène Militaire*, p. 267. Rations have been carried in Algeria sufficient for eight days (letter from French officer), as well as great bundles of fire-wood; but then some of the equipment is left. Also in the above table only 30 cartridges are included; 30 more would increase the weight to 72 lb.

† This is the old knapsack, which is to be superseded by a lighter one.

The rifle carried by the greater part of the infantry is heavier by nearly two pounds than the fusilier rifle, the bayonet of which may be taken off and carried as a sidearm.

The infantry soldier (musketeer) carries 54 lb 81½ grammes (Prussian),* or 59 lb 11·6 ounces (English).

The fusilier soldier carries 52 lb 301 grammes, or 58 lb 3·6 ounces (English).

Russian Infantry Soldier.†

Articles.	English Weight. lb	oz.
Cap and ornament,	...	7
Pouch, with 60 rounds of cartridge,	6	9
Belts, without pouch and sword,	1	5
Pack straps,	1	5
Sword and scabbard,	3	1
Rifle complete (bayonet and ramrod,	10	8
Pack,	6	9
Articles carried in the packs and over them :—		
Outside—Mess tin,	1	5
Greatcoat,	8	12
Inside—Two linen shirts,	1	12
One pair cloth trousers,	3	1
Carry forward,	44	10
Brought forward,	44	10
Inside—One pair boots,	3	12·7
Drawers and linen for feet,	1	5
Brushes,	...	14
Uniform, with summer trousers,	3	12·7
Knife and scissors,	...	10·5
Comb and looking-glass,	...	10·5
Screwdriver for rifle,	...	4·7
Bashlik (hood over the cap),	...	14
Dress cap, worn only in regiment, not in camp,	2	13
	59	11·1

SECTION II.

CARRIAGE OF THE NECESSARIES AND ARMAMENT.

The equipment of the cavalry soldier is in great part carried by the horse; but I have been informed that the mode in which the cavalry valise is arranged is not comfortable to the men. The total weight carried by the horse appears also to be large. A soldier has personal and horse equipments equal to nearly his own weight. I am not competent to pronounce on the necessity of this, but it is a fact that in light-cavalry regiments the horse now carries nearly 19 stone weight, although the rider is on average under 10 stone.

In the case of the infantry soldier, who carries the weights himself, the greatest care is necessary to place them in the manner least likely to detract from his efficiency or to injure his health. If it were possible to let a man, in European countries, carry nothing but his armament and water-bottle, as in India, much more work would be got out of him, longer marches would be made, and he would show greater endurance on the day of action. But such an arrangement is impossible, as transport could not be provided, and the alternative of leaving a man without his necessaries is not to be thought of. But it cannot be too strongly impressed on all commanding officers, that every ounce of weight saved is a gain in efficiency. The Prussians, in the war of 1866, obtained waggons whenever they could to carry the knapsacks, and the

* The Prussian pound is now equal to ½ kilogramme, or 500 grammes.

† From Dr Heyfelder's "Camp of Krasnoe-Selo," German edition, 1868.

comparison between the condition of the men thus relieved and those who could not be so, was striking.* I am also convinced that a change of opinion must be brought about in the army on a very material point. Some officers believe that as the men must carry weights in war, they ought to carry them on all occasions during peace, so that the men may be accustomed to them; and they attempt to strengthen their position by referring to the custom of the Romans, who exercised their men in peace with heavier weapons than those used in war. But this example is not applicable. A man should be exercised in the highest degree in any way which may develop his muscles and improve the circulation through his lungs and heart. Any amount of muscular exertion (within, of course, reasonable limits), any degree of practice with weapons, must be good as long as his body is unshackled; but if he is loaded with weights, and especially if the carriage of the weights at all impedes the action of the lungs and heart, then the very exertion which in other circumstances would benefit him must do him harm. The soldier must carry weights sometimes, but it should be a rule not to carry them when he has no immediate need of the various articles. The aim should be the cultivation of the breathing power of his lungs and the power of his muscles to an extent which will enable him to bear his weights, at those times when he must carry them, more easily than if, on a false notion of accustoming him to them, he had been obliged to wear them on all possible occasions.

Sufficient practice with the weights to enable a man to dispose them comfortably, and to make him familiar with them, should of course be given; but a very short teaching will suffice for this.

The weights which an infantry soldier has to carry have already been stated; the mode of disposing of them has now to be considered.

Weights are most easily borne when the following points are attended to:—

1. They must lie as near the centre of gravity as possible. In the upright position the centre of gravity is between the pelvis and the centre of the body, usually midway between the umbilicus and pubis, but varying of course with the position of the body; a line prolonged to the ground passes through the astragalus just in front of the os calcis. Hence weights carried on the head or top of the shoulder, or which can be thrown towards the centre of the hip bones, are carried most easily, being directly over the line of the centre of gravity. When a weight is carried away from this line the centre of gravity is displaced, and, in proportion to the added weight, occupies a point more or less distant from the usual site, until, perhaps, it is so far removed from this that a line prolonged downwards falls beyond the feet; the man then falls, unless, by bending his body and bringing the added weight nearer the centre, he keep the line well within the space which his feet cover.

In the distribution of weights, then, the first rule is to keep the weight near to the centre; hence the old mode of carrying the soldier's greatcoat, viz., on the back of the knapsack, is a mistake, as it puts on weight at the greatest possible distance from the centre of gravity.

2. The weights must in no case compress the lungs, or in any way interfere with the respiratory movements, or the elimination of carbonic acid, or hinder

* See Mr Bostock's able Report in the Army Medical Report, vol. vii. p 359.
I have seen a letter from a Prussian officer, high in rank, and certain to know the fact, stating that the difference in the health of the Prussian soldiers who carried the knapsacks in the Bohemian marches in 1866, and those who did not, was remarkable. The men who had not carried their packs, though they had not had the comfort of their necessaries, were fresh and vigorous and in high spirits; those who had carried them, on the other hand, were comparatively worn and exhausted, And this was with the best military knapsack known.

the transmission of blood through the lungs, or render difficult the action of the heart.

3. No important muscles, vessels, or nerves should be pressed upon. This is self-evident; an example may be taken from the late Regulation pack, the arm-straps of which so pressed on the axillary nerves and veins as to cause numbness, and often swelling of the hands, which I have known last for twenty-five hours.

4. The weights should be distributed as much as possible over several parts of the body.

If we consider the means made use of by those who carry great weights, we find the following points selected for bearing them :—

1. The top of the head. The cause of this is obvious; the weight is completely in the line of centre of gravity, and in movement is kept balanced over it. Of course, however, very great weights cannot be carried in this way.

2. The tops of the scapulæ, just over the supra-spinous fossa and ridge. At this point the weight is well over the centre of gravity, and it is also diffused over a large surface of the ribs by the pressure on the scapula.

3. The hip bones and sacrum. Here, also, the weight is near the centre of gravity, and is borne by the strong bony arch of the hips, the strongest part of the body.*

In addition, great use is always made by those who carry great weights of the system of balance. The packman of England used to carry from 40 ℔ to even 60 ℔ easily thirty miles a-day by taking the top of the scapula for the fixed point, and having half the weight in front of the chest and half behind. In this way he still brought the weight over the centre of gravity. The same point, and an analogous system of balance, is used by the milkmaid, who can carry more weight for a greater distance than the strongest guardsman equipped with the old military accoutrements and pack.

These points must guide us in arranging the weights carried by the soldier. The weight on the head is, of course, out of the question. We have, then, the scapulæ, the hip, and the principle of balance, to take into consideration.

In our army the carriage of the kit and ammunition has always been felt to be a difficulty, and many have been the changes in the infantry knapsacks since the close of the Peninsular war. The method of carriage which has been in use during the last thirty years, though better than some of the older plans, had grave defects, and it is now being superseded by a new equipment.†

The new infantry equipment, proposed by a War Office Committee, appointed by Lord de Grey in 1864, and of which Lieut.-General Henry Eyre was the president, is devised for the purpose of enabling the infantry soldier to carry his weights with greater comfort (and, therefore, to enable him to march farther), and especially to do away with any chance of injuring his

* The girls engaged in some of the works in Cornwall carry immense bags or hampers of sand up steep hills by resting the lower part of the sack on the hip and sacrum, and the upper part on the scapula. It is the same position as that taken by the Turkish porters, who will carry 600 and 800 ℔ some distance; they also sometimes have a band round the forehead fastened to the top of the weight.

† In the former editions I gave descriptions of what, I hope, may now be considered the obsolete Regulation equipment, and of various other plans. But I have thought it unnecessary to repeat these.

heart and lungs.* This committee have presented four reports to the War Office.†

Considerable difficulty was found in fixing the best equipment; in addition to all the points already noted, simplicity and durability, and as much freedom from accidental breakage as could be ensured, were essential; facility of removal and readjustment for emergencies, adaptation for various conditions of service, and suitableness for military exercises, had all to be considered. After passing in review all the known plans, and experimenting on a large scale, the committee at last recommended a plan which, after an extended trial in many regiments, and being submitted to the opinions of many officers, has been finally authorised, and will be gradually issued in place of the old pattern.

The new equipment is essentially based on the yoke-valise plan of the late Colonel Sir Thomas Troubridge, C.B., who had been for many years experimenting on this subject;‡ but it is greatly altered in details in order to avoid the use of copper or iron rods. The two great principles are to use the scapulæ and the sacrum in about equal proportion as carriers of the weight, and to place the weights as near to the body as possible, and as far as could be done, in front as well as behind, so as to avoid the displacement of the centre of gravity. The great advantage of using the sacrum as one of the points of support has been very apparent in the trials of the valise plan. In that way only can the chest be thoroughly relieved; a very great weight can be carried without injury if it is necessary, and apart from that a mechanical advantage of no small moment has been obtained. For the effect of placing the kit and ammunition low down is to free the large muscles of the shoulder and back from the impediment which hinders their action when a knapsack of any kind is carried in its usual place; the bayonet exercise can therefore be much better performed; but more than this, the soldier engaged in a personal struggle is in far better position than with a knapsack on the upper part of the back; for in the latter case, the centre of gravity being displaced (raised and carried backwards), the man has already a tendency to fall back, which tells seriously against him. In the new equipment, on the contrary, the great weights being all below the centre of gravity, rather tend to keep a man steadier and firmer on his legs than otherwise.

In order to gain these advantages, and also to lessen the weight of the equipment, the framed knapsack was abandoned, and a bag or valise substituted, which is large enough to carry the service kit and some provisions.

The woodcuts, although not very complete, will give a general notion of this plan, which is indeed not difficult to comprehend, as it is remarkably simple. The total weight of the whole equipment, as intended for active service, is 4 lb. 8 oz., or with the separate haversack 5 lb.

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* In the chapter on HOME SERVICE I have given the facts about the amount of heart and vessel disease in the army. It appears to be very large, and to be attributable in part, at any rate, to exercise under unfavourable conditions. It is not confined to the infantry, but is common to all branches, and perhaps the disease of the vessels is even greater in degree in the cavalry and artillery. My colleague, Professor Maclean, called the attention of the authorities to this matter in a striking lecture delivered at the Royal United Service Institution, and published in the Journal of the Institution, vol. viii., and from which I gave extracts in the last edition. The army is greatly indebted to Dr Maclean for his clear exposition on this point. The first report of the Committee on Knapsacks contains the evidence to that date.

† Reports of the Committee appointed to inquire into the effect on health of the present system of carrying the Accoutrements, Ammunition, and Kit of Infantry Soldiers.—First Report, 1865; second Report, 1867; third and fourth Reports, 1868.

‡ Sir T. Troubridge's equipment will be found described and figured in the last edition of this work. I have been informed that he had made experiments on this subject for more than fifteen years.

In the first figure the peace equipment is seen. There is a single pouch in front, which can be shifted to one side so as to allow the waist-belt to be opened. The straps running up over the shoulder from the rings are made broad on the scapulæ, they cross on the back like a common pair of braces, and then catching the top of the valise on the other side by a buckle, run under the arm to the ring on the opposite side from which they started. From this ring a strap runs to the bottom of the valise, which is placed resting on

Fig. 92.—No. 1.

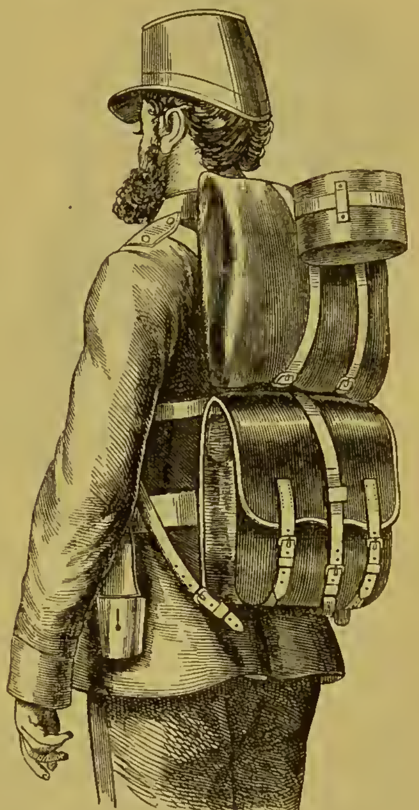

Fig. 93.—No. 2.

the sacrum, as seen in the second figure; by this arrangement the weight of the valise is thrown partly on the shoulder, partly on the sacrum, and is also thrown forward in a line with the centre of gravity. From the ring another strap runs to the waist-belt and supports the ammunition, which thus balances in part the weight behind.

In full service order two pouches are carried in front, as seen in the third figure, each holding 20 rounds; there is also a ball-bag intended to hold loose cartridges for rapid firing, in which, if there be necessity, 20 or even 30 cartridges can be put. There is provision in the valise for 20 more.

The greatcoat is placed above the valise, and being soft gives no obstruction to the action of the muscles of the shoulder.

The canteen can be carried as shown in the second figure; but many officers prefer carrying it on the valise, where there are two loops intended for it.

This equipment is very easy, and leaves the chest perfectly free; it is very simple both in principle and construction, and affords many facilities for carriage of articles, such as the haversack, the waterbottle, blanket, &c.,

which will prove very useful on service. It is of more importance to note here, that it certainly answers all medical requirements; and as it leaves the man very free and unincumbered in his movements, it does away entirely with the stiff unmilitary appearance produced by the old plan.

Fig. 94.—No. 3.

There seems only one sanitary point which has been urged against this equipment, and that is, that a good deal of the back is covered, and that perspiration collects under the valise. Whatever equipment be used there must be retention of perspiration under the covered parts; this is inevitable, and is produced by any knapsack. The valise equipment is no exception to the rule, but it is singular how little perspiration really collects under the valise if the man knows how to manage it. By allowing the top of the valise to fall back half-an-inch, a space is left between the greater part of the valise and back, which allows evaporation, and the loins are kept cool. On the march also, when the waist-belt is unbuckled, both the valise and greatcoat hang loosely and away from the body,* and evaporation goes on. I believe that practically there will be found less accumulation of perspiration than with almost any other plan.

As changes are being made in the equipments of the armies of several European powers, I think it undesirable to describe them here. The old Prussian equipment, which is the best military plan I am acquainted with, did not give entire satisfaction in the Bohemian wars. An alteration has been made by lessening the size of the knapsack, which is no longer cut to the shape of the back, and from which the ammunition-chamber at the top is removed. But from a short trial, I do not think the alteration is an improvement.†

* The army, who will in time to come, and especially in war, feel the benefit of this arrangement (for though details may be altered, I believe the principle of the valise equipment will be always maintained), should know how much it owes to General Eyre, the President of the War Office Committee on Knapsacks, who has laboured at this matter with constant industry and perseverance for years, and has left nothing undone to bring the question to a satisfactory end.

† I refer to the last edition of this work for figures and descriptions of the continental plans, and to the Reports of the War Office Committee on Knapsacks and Accoutrements, for fuller details than can be given here. I ought to mention here that Colonel Carter's equipment is now being worn by the 92d Regiment, and is being tried in another Highland regiment in comparison with the valise equipment. General Eyre's committee, while appreciating the merits of Colonel Carter's plan, did not feel themselves able to adopt it. The same may be said of other plans, many of them very ingenious, which may be seen noticed in their Reports. Among them was one from Colonel Young, with many good points, and an arrangement by Assistant-Surgeon Oliver, of the Rifle Brigade, which, as far as the ammunition is concerned, seems well adapted for cavalry. Mr Oliver's plan for infantry has also been highly praised in Canada, where he has lately brought it forward.

CHAPTER XVI.

DESCRIPTION OF THE METEOROLOGICAL INSTRUMENTS USED IN THE ARMY, AND A FEW REMARKS ON METEOROLOGY.

As the Army Medical Officer is expected to send in meteorological observations at all stations where instruments are provided, it is desirable to give a few plain instructions on the use of these instruments.* For the convenience of beginners, also, I have made a few observations on Meteorology.

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* Only the instruments issued by the Army Medical Department are described in the text. Sir Henry James's very useful book ("Instructions in Meteorology") is issued to all the gentlemen who attend the Army Medical School.

The following is the official circular issued by the Army Medical Department :—

Official Instructions for Reading the Meteorological Instruments.

The observer should make himself thoroughly acquainted with the scale of every instrument, especially with that of the barometer and its attached vernier, and by frequent comparisons ascertain that he and his deputy read the instruments alike, and record the observations accurately.

All observations must be recorded exactly as read. The corrections are to be made only at the end of each month on the "means" of the "sums."

Barometrical observations must be recorded to the third decimal place; thermometrical to the first decimal. When the readings are exactly to the inch or degree, the places for the decimals must be filled up with ciphers.

The observations should be made as quickly as possible, consistently with perfect accuracy, and the observer must avoid breathing on the instruments, particularly the dry and wet bulb, and maximum thermometers.

Barometer Readings.—Note the temperature of attached thermometer in degrees only; by means of the thumb-screw at the bottom adjust the mercury in the cistern to its proper level, the point of the ivory cone, which should just touch the mercury without breaking the surface; then bring the zero line of the vernier to the level of the apex of the column of mercury, and read off in the manner described at pages 15 and 16 of Sir H. James's Book of Instructions.

Thermometer Readings.—The scales are divided to degrees only, but these are so open that the readings can be determined to the tenth of a degree. Practice and attention will insure accuracy.

Maximum Thermometer in Shade.—The maximum thermometer must be hung at such a distance (2 or 3 inches) from the water vessel of the wet-bulb thermometer, that its readings may not be affected by evaporation.

In hanging the maximum, care must be taken that the end of the tube is *slightly inclined downwards*, which will have the effect of assisting in preventing the return of any portion of the column of mercury into the bulb on a decrease of temperature. To read the instrument, gently elevate the end furthest from the bulb to an angle of about 45°, in which position of the instrument note the reading. To reset the thermometer, a gentle shake or swing, or a tap on the wooden frame of the instrument, will cause the excess of mercury to return to the bulb, and it is again ready for use.

Maximum in Sun's Rays, or the Vacuum Solar Radiation Thermometer.—Being constructed on the same principle as the last-mentioned instrument, it must be read in a similar position. After completing the reading, by giving the instrument a slight shake, with the bulb still inclined downwards, the excess of mercury will return to the bulb, and the thermometer be ready for the next observation.

Minimum Thermometer in Shade.—The minimum thermometer must be so hung that the bulb may be about *one inch lower* than the other extremity of the instrument, because in this position the index is less likely to be affected by a rise in temperature.

The extremity of the index furthest from the bulb shows the lowest degree to which the spirit has fallen since the last observation. The reading on the scale corresponding to this is the

SECTION I.

THERMOMETERS FOR TAKING THE TEMPERATURE OF THE AIR.

Maximum Thermometers.

Two maximum thermometers are issued—one to observe the greatest heat in the sun, the other in the shade.

The *Sun Maximum or "Solar Radiation Thermometer"* is found by a glass case (from which the air is removed), containing a mercurial thermometer with a blackened bulb. The case shelters from currents of air; the black bulb absorbs the sun's rays. The tube of the thermometer is slightly bent near the bulb, and a piece of porcelain is inserted which narrows the tube. The effect of this is to make the thermometer self-registering, as, after the mercury has expanded to its fullest extent, instead of retiring into the bulb on cooling, it is stopped by the porcelain, and the mercury breaks between the porcelain and the bulb. The instrument is placed near the ground on wooden supports, and in any place where the sun's rays can freely fall on it.

The *Shade Maximum* is a mercurial thermometer, not enclosed in a case; the tube is bent just above the bulb, and a piece of porcelain or glass is fixed, so that a very small opening only is left between the bulb and the stem. As in the sun maximum, when the mercury has expanded from heat it does not on cooling contract into the bulb, but breaks between the obstruction and the bulb, so that the mercury in the stem remains at the height it had reached during the time of the greatest heat.

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temperature to be recorded. Then, by elevating the bulb, the index will float towards the end of the spirit. When it has *nearly arrived at that point*, the instrument is re-set.

Minimum on Grass Terrestrial Radiation Thermometer is constructed like the last, and the directions above given are also applicable to it.

After reading and re-setting the self-registering thermometers, compare them with the dry-bulb thermometer in order to ascertain that their readings are nearly the same.

Dry and Wet Bulb Thermometers.—Bring the eye on a level with the top of the mercury in the tube of the dry-bulb thermometer, and take the reading, then complete the observation by noting in like manner the reading of the wet-bulb thermometer.

The temperature of the air is given by the former, that of evaporation by the latter. From these data the hygrometrical results are to be calculated by Glaisher's Tables, 3d edition.

Rain Gauge and Measure.—Pour the contents of the gauge into any convenient vessel with a lip, and from this into the glass measure, which has been graduated especially for the gauge, and is only to be used in measuring its contents. It is graduated to the hundredths of an inch.

Anemometer.—The dials are read from left to right. The first on the left records hundreds of miles, the second tens, the third miles, the fourth tenths of a mile, and the fifth hundredths of a mile.

The reading of the anemometer is obtained by deducting from the amount registered by the dials the total sum registered at the period of the preceding observation. The difference between those (subject to a small correction) indicates the velocity or horizontal movement of the air in miles during the interval, and must be entered in the return. When the instrument is first set up, the reading on the dials must be noted, in order that it may be deducted from the total registered by the dials at the end of the first period of observation.

In making observations on the presence of ozone, a box has been found to be unnecessary, equally satisfactory results having been obtained by fixing the paper immediately under the penthouse of the stand, which shelters it sufficiently from a strong light, while it secures proper exposure.

The minimum thermometers are liable to get out of order—first, by carriage, when the index may be wholly or partly driven out of the spirit, or a portion of spirit may become detached from the main column; and, secondly, by slow evaporation of the spirit, which rising in the tube, condenses at the upper end. The first-mentioned errors are corrected by taking the thermometer in the hand, with its bulb downwards, and giving it a swing up and down. The second is remedied by the inclined position of the instrument, which allows the condensed spirit to trickle back to the main column.

N.B.—On no account whatever is artificial heat to be applied to a spirit thermometer. In re-setting the minimum, the index should never be brought quite to the end of the column of spirit.

The thermometer is placed in the shade four feet above the ground, and sufficiently far from any walls to be unaffected by radiation. It should be freely exposed to air, but perfectly protected from the sun's rays.

Minimum Thermometers.

Two minimum thermometers are supplied.

The *Shade Minimum* is an alcoholic thermometer with a small index in the alcohol. It is set by shaking the index *nearly* to the end of the spirit; as the spirit contracts during cold it carries the index down; when it expands again it cannot move the index, but leaves it at the degree of greatest cold. The end of the index farthest from the bulb is the point to read.

This thermometer is placed in the shade four feet above ground, under the same conditions as the former.

The *Grass Minimum or "Terrestrial Radiation Thermometer"* is a thermometer of the same kind, but protected by a glass shield. It is placed almost close to the ground on grass, suspended on little tripods of wood; it is intended to indicate the amount of cooling produced by radiations from the ground.

Common Thermometer.

The dry bulb of the "wet and dry bulb thermometer" is read as a common thermometer.

Reading of the Thermometers.

All these thermometers can be read to tenths of a degree. The maximum and minimum thermometers are read once a-day, usually at 9 A.M.; the former marks the highest point reached on the previous afternoon, and must be so entered on the return; the latter the lowest point reached on the same morning. For the army returns the common thermometer is read twice a-day, at 9 A.M. and 3 P.M.

Range of the Temperature.—The maximum and minimum in shade give most important climatic indications; the difference between them on the same day constitutes the range of the diurnal fluctuation. The range is expressed in several ways.

The extreme daily range in the month or year, is the difference between the maximum and minimum thermometer on any one day.

The extreme monthly or annual range is the difference between the greatest and least height in the mean of month or year, as compared with another.

The mean monthly range is the daily ranges added and divided by the number of days in a month.

The mean yearly range is the monthly ranges added and divided by 12.

Mean Temperature.—The mean temperature of the day is obtained in the following ways:—

(*a.*) Absolutely at Greenwich and other observatories, where by means of photography the height of the thermometer at every moment of the day is registered.

(*b.*) Almost absolutely, if the thermometer is noted every hour, and the mean of the observations are taken.

(*c.*) Approximately in several ways. Taking the mean of the shade maximum and minimum of the same day. In this country, during the cold months (December and January), the result is very close to the truth; but as the temperature increases, a greater and greater error is produced, until in July the mean monthly error is + 1°·9 Fahr., and in some hot days is much greater. In the tropics, the mean of the maximum and minimum must give a result still farther from the truth.

Monthly corrections can be applied to bring these means nearer the truth. Mr Glaisher's correction for this country is as follows :—

Subtract from the monthly mean of the maximum and minimum—

January,	0°·2	May,	1°·7	September,	1°·3
February,	0·4	June,	1·8	October,	1
March,	1·	July,	1·9	November,	0·4
April,	1·5	August,	1·7	December,	0·0

The result is the approximate mean temperature. But this is true only for this country.

In a great number of places the mean temperature of the day and year, as stated in books, is derived solely from the mean of the maximum and minimum, and cannot be considered as correct.

The approximate mean temperature may also be obtained by taking observations at certain times during the day, and applying a correction. Mr Glaisher has given some very valuable tables of this kind,* which can be consulted. The following rules, which are applicable in all parts of the world, are given by Herschel :—†

If observations are taken three times daily—at 7 A.M., 2 P.M., and 9 P.M.—hours which we may denote by t, t', and t''; then

$$\frac{t + t' + 2\ t''}{4} = \text{mean temperature of day.}$$

If the hours are 8 A.M., 3 P.M., and 10 P.M., the formula is—

$$\frac{7\ t + 7\ t' + 10\ t''}{24} = \text{mean of day.}$$

Another simple mode of getting an approximation to the mean temperature is this : Take the mean of the maximum and minimum, and call it t; if a single observation, t', is made with the dry bulb, then—

$$\frac{2\ t + t'}{3}$$

If two observations (t' and t'') are taken beside the maximum and minimum, the rule is—

$$\frac{2\ t + t' + t''}{4}$$

and so on.

The nearest approach to the mean temperature of the day by a single observation is given at from 8 to 9 P.M.; the next is in the morning—about 8 o'clock in July and 10 in December and January.

The nearest approach to the mean annual temperature is given by the mean of the month of October. Observations made from a week before to a week after the 24th April, and again in the corresponding weeks of October, give a certain approximation to the yearly mean temperature (Herschel, "Meteorology," p. 180).

The changes in temperature of any place, during the day or year, are either periodic or non-periodic. The former are dependent on day and night, and on the seasons, *i.e.*, on the position of the place with respect to the sun. The

* On the Corrections to be applied to Meteorological Observations for Diurnal Range, prepared by the Council of the British Meteorological Society, 1850. These corrections are applicable only to this country.

† Meteorology, p. 173.

periodic changes are sometimes termed fluctuations, and the difference between day and night temperatures, or the temperatures of the hottest and coldest months, are often called the amplitudes of the daily or yearly fluctuations.

The non-periodic changes are dependent chiefly on shifting winds, and may either augment or lessen the periodic changes. They are sometimes termed undulations. The thermometer makes, of course, no distinction between these two causes of change, but the observer should distinguish them if possible.

Daily Periodic Changes.—On land the temperature of the air is at its lowest about 3 o'clock A.M., or just before sunrise, and at its maximum about 2 o'clock P.M.; it then falls nearly regularly to 3 o'clock A.M. On water the maximum is nearly an hour later.

The amount of diurnal periodic change is greater on land than on water; in the interior of continents than by the sea-side; in elevated districts than at sea-level. As far as land is concerned, it is least on the sea-coast of tropical islands, as at Kingston in Jamaica, Colombo in Ceylon, Singapore, &c.

Yearly Periodic Changes.—In the northern hemisphere the coldest month is usually January; in some parts of Canada it is February. On the sea the coldest month is later, viz., March. The hottest month is in most places July, in some few August; on the sea it is always August. The coldest days in this country are towards the 21st January; the hottest about the 18th to the 21st July. At Toronto the hottest day is 37 days after the summer solstice, and the coldest 55 days after the winter solstice.

It is thus seen that both for the diurnal and annual alterations of heat the greatest heat is not simultaneous with, but is after, the culmination of the sun; this is owing to the slow absorption of heat by the earth.

The amplitude of the yearly fluctuation is greater on land than sea, and is augmented by land, so that it reaches its highest point in the interior of great extra-tropical continents.

It increases towards the poles for three reasons,—

1. The geographical fluctuation of the earth's position causes a great yearly difference of the angle with which the sun's rays fall on the earth.

2. The duration of incidence of the sun's rays (*i.e.*, the number of hours of sunshine or shade) has greater yearly differences than in the tropics.

3. In the northern hemisphere especially there is a very great extent of land, which increases radiation.

The amplitude of the yearly fluctuation is very small in the tropical land at sea-level. At Singapore it is only 3°·4 Fahr. (Jan. 78·8, July 82·4), while it is immense on continents near the pole. At Jakoutsk, in North Asia, it is 112°·5 (January − 44°·5, and July + 68°).

Undulations or Non-Periodic Changes are irregular changes, and are chiefly caused by the wind, or to a less extent by clouds, rain, and evaporation, and by great and rapid radiation from the earth. In the tropics near the sea they are slightest, and chiefly depend on coast and sea winds. In the higher mountainous regions they are greater; they are greatest in those countries which lie in the debatable region between the cold polar, N. and NE., and the warmer equatorial, S. and SW. winds (anti-trades). They are, however, often dependent on local winds, caused especially by the vicinity of high lands.

In any place there may be great undulations and small fluctuations, or great changes in each way. At Brussels the greatest possible yearly undulation is 90°. In some parts of Canada immense undulations sometimes occur in a day, the thermometer ranging even 50° to 70° in one day.

The hot winds of the rainless deserts have long puzzled meteorologists; they often cause enormous undulations, 50° to as much as 78° Fahr.

Temperature of the Air of any place.

This depends on the following conditions :—

1. *Geographical position as influencing the amount and duration of sun's rays which are received.*—The nearer the equator the hotter. For 23½° on either side the equator the sun's rays are vertical at one period of the year, and are never more oblique than 47°. The mean yearly temperature of the equator is 82° Fahr., of the pole it is about 2°·5 Fahr. The decline from the equator to the pole is not regular; it is more rapid from the equator to 30° than in the higher latitudes.

2. *Relative amount of Land and Water.*—The sun's rays passing through the air with but trifling loss fall on land or on water. The specific heat of land being only one quarter that of water, it both absorbs heat and gives it out more rapidly. Water, on the other hand, absorbs it more slowly, stores up a greater quantity, and parts with it less readily. The temperature of the superficial water, even in the hottest regions, seldom exceeds 80° to 82°, and that of the air is generally below (2° to even 6°) the temperature of the water (J. Davy). Consequently the more land the greater is the heat, and the wider the diurnal and yearly amplitudes of fluctuation. The kind of soil has a great effect on absorption, and the land also transmutes the heat to a certain extent (see SOIL). The evaporation from the water also greatly cools the air (see EVAPORATION).

3. *Elevation of the place above the sea-level.*—The greater the elevation the colder the air, on account—1*st*, of the lessening amount of earth to absorb the sun's rays; and, 2*d*, on account of the greater radiation into free space. The decline of temperature used to be reckoned at about 1° Fahr. for each 300 feet of ascent, but the balloon ascents of Mr Welsh, and especially of Mr Glaisher, have proved that there is no regular decline; there are many currents of warm air even in the upper atmosphere. Still the old rule is useful as an approximation. The amount of decline varies, however, in the same place at different times of the year. In Mr Glaisher's balloon ascents, in a *cloudy* sky, it was about 4° Fahr. for each inch of barometric fall, at first; but when the barometer had fallen 11 inches the decline of temperature was more rapid. Under a *clear* sky there was a fall of 5° Fahr. for each of the first four inches of descent; then 4° per inch till the thirteenth inch of descent, and then 4°·5 for the fourteenth, fifteenth, and sixteenth inches of descent.

The snow-line at any spot, or the height at which snow will lie the whole year, can be approximately reckoned by taking the mean yearly temperature of the latitude at sea-level, and multiplying the difference between that temperature and 32° Fahr. by 300. The aspect of a place, however, and other circumstances, have much to do with the height of the permanent snow-line. The mean temperature of any place can be approximately reckoned in the same way, if the mean temperature of the latitude at sea-level, and the elevation of the place in feet, be known.

4. *Aspect and Exposure, and Special Local Conditions.*—These circumstances chiefly affect a place by allowing free exposure to, or sheltering from, the sun's rays, therefore lessening the number of hours the rays reach the soil, or by furnishing at certain times a large moist surface. Thus the extensive sand-banks of the Mersey cause very rapid alterations of temperature in the water and air by being exposed every twenty-four hours twice to the sun and sky (Adie).

5. *Aërial and Ocean Currents.*—These have a great effect, bringing clouds which block out the sun or produce rain, or which, in the case of ocean currents, cool or warm the air. The cold polar sea currents and the warm equa-

torial (like the Gulf-stream) in some cases almost determine, and always greatly influence, the temperature of a place.

6. *Nature of the Soil.*—On this point little is yet known, but it is certain that some soils easily absorb heat; others do not. The moist and clayey soils are cold; the dry hard rocks and dry sands are hot.

The hottest places on the earth are—in the eastern hemisphere, near the Red Sea, at Massava and Khartoum (15° N.L.), and on the Nile in Lower Nubia; annual temperature = 90°·5 Fahr.; in the western hemisphere, on the Continent, near the West Indies, the annual temperature is 81°·5. These are sometimes called the climatic poles of heat. The poles of cold are in Siberia (Jakoutsk to Ustjausk, 62° N.), and near Melville Island.

Isothermal Lines.—These are lines drawn on charts, and were proposed by Humboldt to connect all places having the same mean annual temperature. The various conditions just noted cause these lines to deviate more or less from the lines of latitude. The isothermal lines are now drawn to represent the places of the same mean monthly, or mean winter or summer temperature.

The lines of mean summer temperature (three months, June, July, August) are called isotheral; those of mean winter temperature (December, January, and February) are called isochcimonal.

SECTION II.

HYGROMETERS—HUMIDITY OF THE AIR.

The amount of watery vapour in the air can be determined in several ways; by direct weighing, by Daniell's or Regnault's hygrometer, by the hair hygrometer, and by the dry and wet bulbs. The method by the dry and wet bulb thermometers has been adopted by the Army Medical Department, and observations are taken twice daily (9 A.M. and 3 P.M.) The instruments are not self-registering, and are simply read off. They are placed in the shade, four feet above the ground, the bulbs freely exposed to the air, but not exposed to the effect of radiant heat from brick walls, &c. The wet bulb is covered with muslin, which is kept moistened by cotton twisted round the bulb and then passing into the water vessel; the cotton is soaked in solution of carbonate of soda, or boiled in ether to free it from fat, so that water may ascend easily in it by capillary attraction; the water must be either rain or distilled water. The dew-point, the weight of a cubic foot of vapour, and the relative humidity, are then taken from Mr Glaisher's tables.*

Definition of these terms.—The dew-point is the temperature when the air is just saturated with moisture, so that the least further fall would cause a deposit of water. The quantity of vapour which can be taken up and be made quite invisible to the senses varies with temperature. The following table gives the weight of a cubic foot of vapour, or to use the common, though not quite accurate, phrase, the weight of vapour in a cubic foot of air at different temperatures when the air is saturated with moisture.

The dew-point is obtained *directly* by Daniell's or Regnault's hygrometer, which enables us to cool and note the temperature of a bright surface until the dew is deposited on it, or by means of the dry and wet bulbs.

Unless the air is saturated, the temperature of the wet bulb (*i.e.*, the temperature of evaporation) is always above the dew-point, but is below the temperature of the dry bulb, being reduced by the evaporation. If the dry and wet bulbs are of the same temperature, the air is saturated with moisture,

* Hygrometrical Tables, 3d edition, 1863. A copy is now sent to each station.

and the temperature noted is the dew-point; if they are not of the same temperature, the dew-point is at some distance below the wet bulb temperature. It can then be calculated out in two ways.

Weight in Grains of a Cubic Foot of Vapour, under the pressure of 30 inches of Mercury for every degree of temperature from 0° to 100°. The temperature is the dew-point, and the weight of vapour is the weight which can be sustained at that temperature without being visible.

Temp. Fahr.	Weight in grains of a Cubic Foot of Vapour.	Temp. Fahr.	Weight in grains of a Cubic Foot of Vapour.	Temp. Fahr.	Weight in grains of a Cubic Foot of Vapour.	Temp. Fahr.	Weight in grains of a Cubic Foot of Vapour.
°	grs.	°	grs.	°	grs.	°	grs.
32	2·13	50	4·10	67	7·27	84	12·40
33	2·21	51	4·24	68	7·51	85	12·78
34	2·30	52	4·39	69	7·76	86	13·17
35	2·48	53	4·55	70	8·01	87	13·57
36	2·48	54	4·71	71	8·27	88	13·98
37	2·57	55	4·87	72	8·54	89	14·41
38	2·66	56	5·04	73	8·82	90	14·85
39	2·76	57	5·21	74	9·10	91	15·29
40	2·86	58	5·39	75	9·39	92	15·74
41	2·97	59	5·58	76	9·69	93	16·21
42	3·08	60	5·77	77	9·99	94	16·69
43	3·20	61	5·97	78	10·31	95	17·18
44	3·32	62	6·17	79	10·64	96	17·68
45	3·44	63	6·38	80	10·98	97	18·20
46	3·56	64	6·59	81	11·32	98	18·73
47	3·69	65	6·81	82	11·67	99	19·28
48	3·82	66	7·04	83	12·03	100	19·84
49	3·96						

(*a.*) By Mr Glaisher's factors. By comparison of the result of Daniell's hygrometer and the dry and wet bulb thermometers for a long term of years, Mr Glaisher has deduced an empirical formula, which is thus worked. Take the difference of the dry and wet bulb, and multiply it by the factor which stands opposite the *dry bulb* temperature in the following table, deduct the product from the *dry* bulb temperature, the result is the dew-point.

The dew-point being obtained, the amount of vapour in a cubic foot of air is at once seen by looking at the table before given. From this formula Mr Glaisher's tables have been calculated.

(*b.*) *Apjohn's Formula.*—From a most philosophical and exhaustive analysis of the conditions of this complicated problem, Dr Apjohn has derived his celebrated formula which is now in general use. Reduced to its most simple expression, it is thus worked:—A table of the elastic tension of vapour, in inches of mercury at different temperatures, must be used. From this table take out the elastic tension of the temperature of the *wet* thermometer, and call it f. Let d be the difference of the two thermometers, and h the observed height of the barometer. Apjohn's formula then enables us to calculate the elastic tension of the dew-point, which we will call F; and this being known by looking in the table, we obtain, opposite this elastic tension, the dew-point temperature.

If the temperature be above 32° the formula is—

$$F = f - \frac{d}{88} \times \frac{h}{30};$$

If below 32° the formula is—

$$F = f - \frac{d}{96} \times \frac{h}{30}.$$

Or the formula may be thus expressed—

$$F = f - \cdot 0114 \times d \times \frac{h - f}{30}.$$

Glaisher's Factors:—

Reading of Dry-bulb Therm.	Factor.	Reading of Dry-bulb Therm.	Factor.	Reading of Dry-bulb Therm.	Factor.	Reading of Dry-bulb Therm.	Factor.
°		°		°		°	
10	8·78	33	3·01	56	1·94	79	1·69
11	8·78	34	2·77	57	1·92	80	1·68
12	8·78	35	2·60	58	1·90	81	1·68
13	8·77	36	2·50	59	1·89	82	1·67
14	8·76	37	2·42	60	1·88	83	1·67
15	8·75	38	2·36	61	1·87	84	1·66
16	8·70	39	2·32	62	1·86	85	1·65
17	8·62	40	2·29	63	1·85	86	1·65
18	8·50	41	2·26	64	1·83	87	1·64
19	8·34	42	2·23	65	1·82	88	1·64
20	8·14	43	2·20	66	1·81	89	1·63
21	7·88	44	2·18	67	1·80	90	1·63
22	7·60	45	2·16	68	1·79	91	1·62
23	7·28	46	2·14	69	1·78	92	1·62
24	6·92	47	2·12	70	1·77	93	1·60
25	6·53	48	2·10	71	1·76	94	1·60
26	6·08	49	2·08	72	1·75	95	1·59
27	5·61	50	2·06	73	1·74	96	1·59
28	5·12	51	2·04	74	1·73	97	1·59
29	4·63	52	2·02	75	1·72	98	1·58
30	4·15	53	2·00	76	1·71	99	1·58
31	3·70	54	1·98	77	1·70	100	1·57
32	3·32	55	1·96	78	1·69		

The dew-point being known, the weight of a cubic foot of vapour, and the amount of elastic tension, expressed in inches of mercury (if it is wished to learn this), are taken from tables; the relative humidity is got by calculation.

The relative humidity is merely a convenient term to express comparative dryness or moisture. Complete saturation being assumed to be 100, any degree of dryness may be expressed as a percentage of this, and is obtained at once by dividing the weight of vapour actually determined by the weight of vapour which would have been present had the air been saturated.

In order to save trouble, all these points, and other matters of interest,

TABLE *of the Relative Humidity given by the difference between the Dry and Wet Bulb.*

Temperature of the Dry Bulb.	Difference between the Dry and Wet Bulb.															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Relative Humidity, Saturation=100.															
90	100	95	90	85	81	77	73	69	65	62	59	56	53	50	47	44
89	100	95	90	85	81	77	73	69	65	61	58	55	52	49	46	43
88	100	95	90	85	81	77	73	69	65	61	58	55	52	49	46	43
87	100	95	90	85	81	77	73	69	65	61	58	55	52	49	46	43
86	100	95	90	85	80	76	72	68	64	61	58	55	52	49	46	43
85	100	95	90	85	80	76	72	68	64	61	58	55	52	49	46	43
84	100	95	90	85	80	76	72	68	64	60	57	54	51	48	45	43
83	100	95	90	85	80	76	72	68	64	60	57	54	51	48	45	42
82	100	95	90	85	80	76	72	68	64	60	57	54	51	48	45	42
81	100	95	90	85	80	76	72	68	64	60	56	53	50	47	44	41
80	100	95	90	85	80	75	71	67	63	59	56	53	50	47	44	41
79	100	95	90	85	80	75	71	67	63	59	56	53	50	47	44	41
78	100	94	89	84	79	75	71	67	63	59	56	53	50	47	44	41
77	100	94	89	84	79	75	71	67	63	59	56	53	50	47	44	41
76	100	94	89	84	79	75	71	67	63	59	55	52	49	46	43	40
75	100	94	89	84	79	74	70	66	62	58	55	52	49	46	43	40
74	100	94	89	84	79	74	70	66	62	58	55	52	48	45	43	40
73	100	94	89	84	79	74	70	66	62	58	54	51	48	45	42	40
72	100	94	89	84	79	74	69	65	61	57	54	51	48	45	42	39
71	100	94	88	83	78	73	69	65	61	57	53	50	47	44	41	38
70	100	94	88	83	78	73	69	65	61	57	53	50	47	44	41	38
69	100	94	88	83	78	73	68	64	60	56	53	50	47	44	41	38
68	100	94	88	83	78	73	68	64	60	56	52	49	46	43	40	37
67	100	94	88	83	78	73	68	64	60	56	52	49	46	43	40	37
66	100	94	88	83	78	73	68	61	60	56	52	48	45	42	40	37
65	100	94	88	83	78	73	68	63	59	55	51	48	45	42	39	36
64	100	94	88	82	77	72	67	63	59	55	51	48	45	42	39	36
63	100	94	88	82	77	72	67	63	59	55	51	47	44	41	38	35
62	100	94	88	82	77	72	67	62	58	55	50	47	44	41	38	35
61	100	94	88	82	77	72	67	62	58	54	50	47	44	41	38	35
60	100	94	88	82	76	71	66	62	58	54	50	46	43	40	37	34
59	100	94	88	82	76	71	66	61	57	53	49	46	43	40	37	34
58	100	93	87	81	76	71	66	61	57	53	49	46	43	40	37	34
57	100	93	87	81	75	70	65	61	57	53	49	45	42	39	36	33
56	100	93	87	81	75	70	65	60	56	52	48	44	41	38	35	32
55	100	93	87	81	75	70	65	60	56	52	48	44	41	38	35	32
54	100	93	86	80	74	69	64	59	55	51	47	43	40	37	34	31
53	100	93	86	80	74	69	64	59	55	51	47	43	39	36	33	30
52	100	93	86	80	74	69	64	59	54	50	46	42	39	36	33	30
51	100	93	86	80	74	68	63	58	54	50	46	42	38	35	32	29
50	100	93	86	80	74	68	63	58	53	49	45	41	37	34	31	29
49	100	93	86	79	73	67	62	57	53	49	45	41	37	34	31	28
48	100	93	86	79	73	67	62	57	52	48	44	40	36	33	30	
47	100	93	86	79	73	67	61	56	51	47	43	39	36	33	30	
46	100	93	86	79	73	67	61	56	51	47	43	39	35	32	29	
45	100	92	85	78	72	66	60	55	50	46	42	38	34	31	28	
44	100	92	84	78	71	65	59	54	49	45	41	37	34	31	28	
43	100	92	84	78	71	65	59	54	49	45	41	37	34	31	28	
42	100	92	84	78	71	66	60	54	49	44	40	36	43	30	27	
41	100	92	84	77	70	64	58	53	48	43	39	35	31	28		
40	100	92	84	77	69	63	57	51	46	42	38	34	31			
39	100	92	84	77	69	63	57	52	47	42	38	34				
38	100	91	83	75	68	62	56	50	45	41	37					
37	100	91	83	75	68	61	55	49	44	39						
36	100	91	82	74	66	59	53	47	42							
35	100	90	80	72												
34	100	89	79	72												
33	100	89	78	70												
32	100	87	75													

such as the weight of a cubic foot of dry air, or of mixed dry and moist air, are given in Mr Glaisher's Hygrometrical Tables, which are now sent to the principal stations, and which all medical officers are advised to get. But in the absence of these, the tables given in this chapter, and Glashier's factors, will enable the chief points to be determined; also the table, page 440, which is extracted from Mr Glaisher's larger tables, will be found useful. It gives the relative humidity, and if the weight of a cubic foot of vapour (in the table already given, p. 438), at the temperature of the dry bulb, be multiplied by the relative humidity, and then divided by 100, the actual weight of vapour in the air at the time of observation is obtained.*

To read the table take the temperature of the dry bulb, and the difference between it and the wet bulb, and look in the table at the intersection of the two columns.

The amount of watery vapour can also be told by a hair hygrometer. A modification of Saussure's hygrometer is still used in France. A human hair, freed from fat by digestion in liquor potassæ or ether, is stretched between a fixed point and a small needle, which traverses a scale divided into 100 parts. As the hair elongates or dries, the needle moves and indicates the relative humidity. The scale is graduated by wetting the hair for complete saturation, and by placing it over sulphuric acid of known strength for different degrees of saturation. A very delicate instrument is thus obtained, which indicates even momentary changes in moisture. On comparison with the wet and dry bulb, I have found that it gives accordant results for three or four months; it then loses its delicacy, and requires to be a little wound up. If compared with the dry and wet bulb, the hair hygrometer seems to be exact enough for experiments in ventilation, for which it is adapted from its rapidity of indication. The amount of watery vapour in the air has a considerable effect on the temperature of a place. Hermann von Schlagintweit† has pointed out that the differences between the temperature marked in the sun and shade by two maximum thermometers are chiefly dependent on the amount of humidity. The maxima of insolation (measured by the difference between the sun and shade thermometers) occur in those stations and on those days when humidity is greatest. Thus, at Calcutta, the relative humidity being 88 to 93, the insolation (or difference between the thermometers) is 50° Fahr.; at Bellori, the relative humidity being 60 to 65, the insolation is 8° to 11°. These results are explained by Tyndall's observations, which show that the transparent humidity will scarcely affect the sun's rays striking on the sun thermometer, while it greatly obstructs the radiation of invisible heat from the thermometer; when the air is highly charged with moisture, the sun thermometer is constantly gaining heat from the sun's rays, while it loses little by radiation, or if it does lose by radiation, gains it again from the air.

When watery vapour mixes with dry air, the volume of the latter is augmented; the weight of a cubic foot of dry air at 60° Fahr. is 536·28 grains, and that of a cubic foot of vapour at 60° is 5·77 grains; the conjoint weights would be 542·05 grains at 60°, but, owing to the enlargement of the air, the actual weight of a cubic foot of saturated air at 60° is only 532·84. It will be useful to extract a table from Mr Glaisher's work, showing the weight of a cubic foot of saturated air.

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* Or, what is the same thing, multiply by the relative humidity, with a decimal point before it.

† Proceedings of Royal Soc., vol. xiv. p. 111, 1865.

Weight of a Cubic Foot of Saturated Air under the pressure of 30 *inches of Mercury.*

Temp. Fahr.	Weight of a Cubic Foot of Air saturated with Vapour.	Temp. Fahr.	Weight of a Cubic Foot of Air saturated with Vapour.	Temp. Fahr.	Weight of a Cubic Foot of Air saturated with Vapour.	Temp. Fahr.	Weight of a Cubic Foot of Air saturated with Vapour.
°	grs.	°	grs.	°	grs.	°	grs.
0	606·03	26	572·85	51	543·21	76	514·55
1	604·69	27	571·63	52	542·06	77	513·40
2	603·37	28	570·42	53	540·89	78	512·26
3	602·05	29	569·20	54	539·75	79	511·13
4	600·72	30	567·99	55	538·60	80	509·97
5	599·40	31	566·79	56	537·45	81	508·81
6	598·11	32	565·58	57	536·30	82	507·67
7	596·80	33	564·38	58	535·16	83	506·51
8	595·51	34	563·18	59	534·00	84	505·36
9	594·24	35	561·99	60	532·84	85	504·19
10	592·94	36	560·79	61	531·69	86	503·05
11	591·64	37	559·59	62	530·55	87	501·90
12	590·35	38	558·42	63	529·42	88	500·74
13	589·08	39	557·22	64	528·27	89	499·57
14	587·82	40	556·03	65	527·14	90	498·43
15	586·55	41	554·87	66	526·01	91	497·25
16	585·30	42	553·69	67	524·86	92	496·07
17	584·03	43	552·52	68	523·71	93	494·90
18	582·76	44	551·36	69	522·55	94	493·74
19	581·51	45	550·19	70	521·41	95	492·56
20	580·26	46	549·01	71	520·27	96	491·39
21	579·03	47	547·85	72	519·12	97	490·19
22	577·78	48	546·69	73	517·98	98	489·01
23	576·56	49	545·53	74	516·82	99	487·83
24	575·32	50	544·36	75	515·69	100	486·65
25	574·08						

SECTION III.

BAROMETER.

A good mercurial barometer is supplied to many army stations; the scale is brass, graduated to 20ths or $\frac{1}{2}$-tenths on the scale, and is read to $\frac{2}{1000}$ths by means of a vernier. There is a movable bottom to the cistern, which is worked up and down by a screw, so as to keep the mercury in the cistern at the same level. Correction for capacity is thus avoided.

To fix the Barometer.—Choose a place with a good light, yet protected from direct sunlight and rain; fix the frame sent with the barometer very carefully with a plumb-line, so as to have it exactly perpendicular; then hang the barometer on the hook, and adjust it gently by means of the three screws at the bottom, so that it hangs truly in the centre. Test this by the plumb-line (a 4 oz. weight tied to a string will do), and then unscrew the bottom of the cistern till the ivory point is seen.

Before fixing the barometer the bottom should be unscrewed till the mer-

cury is two or three inches from the top; the barometer should be suddenly inclined, so as to let the mercury fall against the top; if there is no air it will do this with a dull thud; if there be air there is no thud; in that case turn the barometer upside down, and tap the side forcibly till you see the globule of air passing up the tube through the mercury into the cistern. Do not be afraid of doing this; if the screw at the bottom be not too far unscrewed there is no danger of any damage to the instrument.

Reading of Barometer.—Read the attached thermometer first; then adjust the cistern, so that the ivory point, perceptible through the glass wall of the cistern, seems just to touch the point of the image in the mercury. Then adjust the vernier, so as to cut off the light from the *top* of the mercury. Then read the scale with the bottom of the vernier.

I have found that a little difficulty is experienced in understanding the vernier by those who are not accustomed to such instruments. It will be, probably, comprehended from a little description, read with the instrument before us. On the scale of the barometer itself, it will be seen that the smallest divisions correspond to half-tenths; that is, to $\frac{5}{100}$ths of an inch (= ·05). The height of the mercury can be read so far on the scale itself. The vernier is intended to enable us to read the amount of space the top of the mercury is above or below one of these half-tenth lines. It will be observed that the vernier is divided into twenty-five lines; but on adjusting it, so that its lower line corresponds with a line indicating an inch, it will be seen that its twenty-five divisions only equal twenty-four half-tenth divisions on the scale. The result is, that each division on the vernier is $\frac{1}{25}$th less than a half-tenth division on the scale. One $\frac{1}{25}$th of a half-tenth is $\frac{2}{1000}$ths of an inch (0·5 ÷ 25 = ·002 inch).

This being understood, adjust the vernier so that its *lowest* line accurately corresponds to any line on the scale. It will then be seen that its lowest line but one is a little distance below (in fact, ·002 inch) the next line on the fixed scale. Raise now the vernier, so that its second line shall correspond to the line on the scale to which it was a little below; and of course the bottom of the vernier must be raised ·002 inch above the line it first corresponded with. If the next line, the third on the vernier, be made to correspond with the line on the scale just above it, the bottom of the scale must be raised double this (·004 inch) above the line it was first level with; if the next line on the vernier be made to correspond with a line on the scale, the scale is raised ·006, and so on. Each division on the vernier equals ·002 inch, and each five divisions equals $\frac{1}{100}$th, or ·01 inch.

The barometer is read thus. When the top of the mercury is between the half-tenth lines, and the vernier is adjusted to the top of the mercury, see what line on the vernier above corresponds exactly to a line on the scale. Then read the number on the vernier, counting from the bottom; multiply it by ·002, and the result is the number of hundreds or thousands of an inch the top of the mercury is above the half-tenth line next below it.* Add this number to that already got by direct reading of the fixed scale, and the result is the height of the mercury in inches and decimals of an inch.

Corrections for the Barometer.—The barometer supplied to military stations requires no correction for capacity. There are two constant corrections for all barometers, viz., capillarity and index error. The first depends on the size of the bore, and whether the mercury has been boiled in the tube or not.

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* Instead of multiplying the number on the vernier by ·002, a little practice will enable the calculation to be made at once. On the vernier will be seen the figures 1, 2, 3, 4, and 5; corresponding to the 5th, 10th, 15th, 20th, and 25th lines, and indicating ·01, ·02, ·03, ·04, or ·05 inch. Each line between these numbered lines equals ·002 inch.

Diameter of Tube.	To be added for capillarity, if the mercury has been boiled.
0·1 inch, ...	·070 inches.
0·2 "	·029 "
0·3 "	·014 "
0·4 "	·007 "
0·5 "	·003 "
0·6 "	·002 "

The error for capillarity is notified by the maker. Index error is determined by comparison with a standard barometer. It is indicated by the maker, and is constant for the same barometer. The index and capillarity errors are put together. The capillarity error is always additive; the index error may be subtractive or additive; the two together form a constant quantity.

Correction for Temperature.—The barometer is always registered as if the temperature of the mercury were 32° Fahr. If the temperature of the mercury be above this, the metal expands, and reads higher than it would do at 32°. The amount of expansion of mercury is ·0001001 of its bulk for each degree; but the linear expansion of the brass scale must be also considered. Schumacher's formula is used for the correction—viz.,

h = observed height of barometer in inches.
t = temperature of attached thermometer (Fahr.)
m = expansion of mercury per degree—viz. ·0001001.
l = linear expansion of scale—viz. ·0000104344; normal temperature being 62°.

$$h \times \frac{m\ (t - 32°) - l\ (t - 62°)}{1 + m\ (t - 32°).}$$

To facilitate the correction for temperature, tables are given in Sir H. James's work, which is distributed to medical officers. The shorter table on page 445 may be useful.

Correction for Sea-Level.—Medical officers do not require to make this correction, as what is wanted is to know the actual pressure of the air on the body. As the mercury falls about $\frac{1}{1000}$ (·001 inch)* for every foot of ascent, this amount multiplied by the number of feet must be added to the height, if the place be above sea-level. The temperature of the air has, however, also to be taken into account if great accuracy is required.

When all these corrections have been made, the exact height of the mercury represents the conjoint weights of the oxygen, nitrogen, carbonic acid, and watery vapour of the atmosphere. It is difficult to separate these several weights, and the late observations, which show that the humidity existing at any place is merely local, and that vapour is most unequally diffused through the air, render it quite uncertain what amount of the mercury is supported by the watery vapour. Yet that this has a considerable effect in altering the barometric height, particularly in the tropics, seems certain (Herschel).

The height of the barometer at sea-level differs at different parts of the earth's surface; being less at the equator (29·974) than on either side at 30° N. and S. lat., and lessening again towards the poles, especially towards the south, from 63° to 74° S. lat., where the depression is upwards of an inch. It differs in different places also according to their geographical position and their height above sea-level. Like the thermometer, it is subjected to diurnal and annual periodic changes and to non-periodic undulations.

* The exact amount is a little below this, but varies with altitude; at sea-level the amount is ·000886 for every foot of ascent. See measurement of heights of barometer.

In the tropics the diurnal changes are very steady; there are two maxima and two minima: the first maximum is about 9 A.M.; the first minimum about 3 to 4 P.M.; the second maximum at 10 P.M.; the second minimum at 4 A.M. These changes are, perhaps, chiefly dependent on the watery vapour (Herschel). In this country the diurnal range is less; it falls from midnight to about 4 to 6; rises till 11, and falls again till 4 or 6; then rises till midnight. The undulations depend on the constantly shifting currents af air, rendering the total amount of air over a place heavier or lighter. The wind tends to pass towards the locality of least barometric pressure. In this country the barometer falls with the south-west winds; rises with the north and east; the former are moist and warm, the latter dry and cold winds.

TABLE *for Reduction of Barometer to Freezing Point. The number opposite the temperature of the attached thermometer is to be deducted.*

Temp. of attached Therm.	Corrections for the Barometer at			
	27 inches.	28 inches.	29 inches.	30 inches.
Fahr. degs.	inch.	inch.	inch.	inch.
32	·0086	·0088	·0091	·0094
34	·0134	·0138	·0143	·0148
36	·0183	·0188	·0194	·0201
38	·0231	·0238	·0246	·0255
40	·0279	·0288	·0298	·0309
42	·0327	·0338	·0350	·0362
44	·0375	·0388	·0402	·0416
46	·0423	·0438	·0454	·0470
48	·0471	·0488	·0506	·0523
50	·0519	·0538	·0558	·0577
52	·0568	·0588	·0609	·0630
54	·0616	·0638	·0661	·0684
56	·0664	·0688	·0713	·0738
58	·0712	·0738	·0765	·0791
60	·0760	·0788	·0817	·0845
62	·0809	·0838	·0868	·0898
64	·0857	·0888	·0920	·0951
66	·0906	·0938	·0971	·1005
68	·0954	·0988	·1023	·1058
70	·1000	·1037	·1075	·1112
72	·1049	·1087	·1126	·1165
74	·1097	·1137	·1178	·1218
76	·1146	·1187	·1229	·1272
78	·1194	·1237	·1281	·1325
80	·1241	·1286	·1332	·1378
82	·1289	·1336	·1384	·1432
84	·1338	·1386	·1435	·1485
86	·1385	·1435	·1486	·1538
88	·1433	·1485	·1538	·1591
90	·1482	·1535	·1589	·1644

The isobarometric lines are the lines connecting places with the same mean annual height of barometer.

Measurement of Heights.—The barometer falls when heights are ascended,

as a certain weight of air is left below it. The diminution is not uniform, for the higher the ascent the less weighty the air, and a greater and greater height must be ascended to depress the barometer one inch. This is illustrated by the following table :—*

To lower from	31	inches to	30 =	857	feet must	be ascended.
,,	30	,,	29 =	886	,,	,,
,,	29	,,	28 =	918	,,	,,
,,	28	,,	27 =	951	,,	,,
,,	27	,,	26 =	986	,,	,,
,,	26	,,	25 =	1025	,,	,,
,,	25	,,	24 =	1068	,,	,,
,,	24	,,	23 =	1113	,,	,,
,,	23	,,	22 =	1161	,,	,,
,,	22	,,	21 =	1216	,,	,,
,,	21	,,	20 =	1276	,,	,,
,,	20	,,	19 =	1341	,,	,,
,,	19	,,	18 =	1413	,,	,,

The measurements of heights in this way is of great use to medical officers; the aneroid barometer can be used as high as 5000 feet, and a delicate instrument will measure as little as 4 feet.

A great number of plans are in use for calculating heights. It can be done readily by logarithms, but then medical officers may not possess a table of logarithms.

The simplest rule of all is one derived from Laplace's formula. Mr Ellis † has lately stated this formula as follows :—Multiply the difference of the barometric readings by 52400, and divide by the sum of the barometric readings. If the result be 1000, 2000, 3000, 4000, or 5000, add 0, 0, 2, 6, 14, respectively. Subtract $2\frac{1}{3}$ times the difference of the temperatures of the mercury. Multiply the remainder by a number obtained by adding 836 to the sum of the temperatures of the air, and dividing by 900. A correction must also be made for latitude, which can be done by Table III. p. 449.

Tables such as those given by Delcros and Oltmanns are very convenient for estimating heights by the barometer. A table less long than these, but based on the same principle, has been given by Negretti and Zambra in their useful work,‡ and as it is the easiest formula I know, I have copied it.

A good mercurial barometer, with an attached thermometer, or an aneroid compensated for temperature, is required. A thermometer to ascertain the temperature of the air is also required. Two barometers and two thermometers, which can be observed at the same moment at the upper and lower stations, are desirable.

Supposing, however, there is but one barometer, take the height at the lower station, and correct for temperature to 32°, according to the table given at page 445. Take the temperature of the air. Ascend as rapidly as possible to the upper station, and take the height of the barometer (correcting it to 32°) and the temperature of the air; then use the following tables, taken from

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* The height can be taken readily from this table, by calculating the number of feet which must have been ascended to cause the observed fall, and then making a correction for temperature, by multiplying the number obtained from the table, which may be called A, by the formula (t is the temperature of the lower, and t' of the upper station).

$$\left(1 + \frac{t + t' - 64}{900}\right) \times A \,.$$

† Proceedings of Royal Society, 1865, No. 75, p. 283.

‡ A Treatise on Meteorological Instruments, by Negretti and Zambra, 1864.

Negretti and Zambra's work. If the height is less than 300 feet, Tables II., III., and IV. need not be used.

"Table I. is calculated from the formula, height in feet = 60,200 (log. 29·922—log. B) + 952; where 29·922 is the mean atmospheric pressure at 32° Fahr., and the mean sea-level in latitude 45°; and B is any other barometric pressure; the 925 being added to avoid minus signs in the table.

"Table II. contains the correction necessary for the mean temperature of the stratum of air between the stations of observation; and is computed from Regnault's co-efficient for the expansion of air, which is ·002036 of its volume at 32° for each degree above that temperature.

"Table III. is the correction due to the difference of gravitation in any other latitude, and is found from the formula, $x = 1 + \cdot 00265 \cos. 2 \text{ lat.}$

"Table IV. is to correct for the diminution of gravity in ascending from the sea-level.

"To use these tables: The barometer readings at the upper and lower stations having been corrected and reduced to temperature 32° Fahr., take out from Table I. the numbers opposite the corrected readings of the two barometers, and subtract the lower from the upper. Multiply this difference successively by the factors found in Tables II. and III. The factor from Table III. may be neglected unless precision is desired. Finally, add the correction taken from Table IV." (Negretti and Zambra.)

In the table the barometer is only read to 10ths, but it should be read to 100ths (·01) and 1000ths (·001), and the number of feet corresponding to these amounts calculated from the table, which is easy enough.

TABLE I.—*Approximate Height due to Barometric Pressure.*

Inches of Barometer.	Feet.	Inches of Barometer.	Feet.	Inches of Barometer.	Feet.
31·0	0	28·9	1,833	26·8	3,806
30·9	84	·8	1,924	·7	3,904
·8	169	·7	2,015	·6	4,002
·7	254	·6	2,106	·5	4,100
·6	339	·5	2,198	·4	4,199
·5	425	·4	2,290	·3	4,298
·4	511	·3	2,382	·2	4,398
·3	597	·2	2,475	·1	4,498
·2	683	·1	2,568	26·0	4,598
·1	770	28·0	2,661	25·9	4,699
30·0	857	27·9	2,754	·8	4,800
29·9	944	·8	2,848	·7	4,902
·8	1,032	·7	2,942	·6	5,004
·7	1,120	·6	3,037	·5	5,106
·6	1,208	·5	3,132	·4	5,209
·5	1,296	·4	3,227	·3	5,312
·4	1,385	·3	3,323	·2	5,415
·3	1,474	·2	3,419	·1	5,519
·2	1,563	·1	3,515	25·0	5,623
·1	1,653	27·0	3,612	24·9	5,728
29·0	1,743	26·9	3,709	24·8	5,833

TABLE I.—*Approximate Height due to Barometric Pressure*—continued.

Inches of Barometer.	Feet.	Inches of Barometer.	Feet.	Inches of Barometer.	Feet.
24·7	5,939	23·1	7,690	21·5	9,567
·6	6,045	23·0	7,803	·4	9,689
·5	6,152	22·9	7,917	·3	9,811
·4	6,259	·8	8,032	·2	9,934
·3	6,366	·7	8,147	·1	10,058
·2	6,474	·6	8,262	21·0	10,182
·1	6,582	·5	8,378	20·9	10,307
24·0	6,691	·4	8,495	·8	10,432
23·9	6,800	·3	8,612	·7	10,558
·8	6,910	·2	8,729	·6	10,684
·7	7,020	·1	8,847	·5	10,812
·6	7,131	22·0	8,966	·4	10,940
·5	7,242	21·9	9,085	·3	11,069
·4	7,353	·8	9,205	·2	11,198
·3	7,465	·7	9,325	·1	11,328
23·2	7,577	21·6	9,446	20·0	11,458

TABLE II.—*Correction due to Mean Temperature of the Air; the Temperature of the Upper and Lower Stations being added and divided by* 2.

Mean Temp.	Factor.	Mean Temp.	Factor.	Mean Temp.	Factor.
10°	0·955	35°	1·006	60°	1·057
11	·957	36	1·008	61	1·059
12	·959	37	1·010	62	1·061
13	·961	38	1·012	63	1·063
14	·963	39	1·014	64	1·065
15	·965	40	1·016	65	1·067
16	·967	41	1·018	66	1·069
17	·969	42	1·020	67	1·071
18	·971	43	1·022	68	1·073
19	·974	44	1·024	69	1·075
20	·976	45	1·026	70	1·077
21	·978	46	1·029	71	1·079
22	·980	47	1·031	72	1·081
23	·982	48	1·033	73	1·083
24	·984	49	1·035	74	1·086
25	·986	50	1·037	75	1·088
26	·988	51	1·039	76	1·090
27	·990	52	1·041	77	1·092
28	·992	53	1·043	78	1·094
29	·994	54	1·045	79	1·096
30	·996	55	1·047	80	1·098
31	0·998	56	1·049	81	1·100
32	1·000	57	1·051	82	1·102
33	1·002	58	1·053	83	1·104
34	1·004	59	1·055	84	1·106

Table III.—*Correction due to Difference of Gravitation in different Latitudes.*

Latitude.	Factor.	Latitude.	Factor.	Latitude.	Factor.
80°	0·99751	50°	0·99954	20°	1·00203
75	0·99770	45	1·00000	15	1·00230
70	0·99797	40	1·00046	10	1·00249
65	0·99830	35	1·00090	5	1·00261
60	0·99868	30	1·00132	0	1·00265
55	0·99910	25	1·00170		

Table IV.

Height in Thousand Feet.	Correction Additive.	Height in Thousand Feet.	Correction Additive.
1	3	9	26
2	5	10	30
3	8	11	33
4	11	12	37
5	14	13	41
6	17	14	44
7	20	15	48
8	23		

Example.—On 21st October 1852, when Mr Welsh ascended in a balloon, at 3h. 30m. P.M., the barometer, corrected and reduced, was 18·85, the air temperature 27°, while at Greenwich, 159 feet above the sea, the barometer at the same time was 29·97 inches, air temperature 49°, the balloon not being more than five miles S.W. from over Greenwich; required its elevation.

			Feet.
Barometer in Balloon .	18·85, Table I.	=	13007
„ at Greenwich,	29·97, „		883
			12124
Mean Temperature, 38°, Table II. Factor,		.	1·012
			12269·
Latitude $51\frac{1}{2}$°, Factor from Table III., .		.	·99941
			12262
Correction from Table IV., ...		.	38
			12300
Elevation of Greenwich, . . .		.	159
„ Balloon, ...		.	12459

Weight of the Air.—The barometer expresses the weight of the air in inches of mercury. The actual weight can be determined if the reading of the barometer, temperature, and humidity are all known.

The weight of a cubic foot of dry air at 32° Fahr., and normal pressure, is 566·85 grains. For any other temperature the weight can be calculated. Multiply the co-efficient of the expansion of air (viz., ·0020361 for 1° Fahr.) by the number of degrees above 32, the sum added to unity will give the volume of a cubic foot of dry air at that temperature. Divide 566·85 by the number so obtained. The result is the weight of the dry air at the given temperature. The following Table is copied from Glaisher:—

TABLE *Showing the Weight in Grains of a Cubic Foot of Dry Air, under the pressure of* 30 *inches of Mercury, for every degree from* 0° *to* 100°.

Temp. Fahr.	Weight of a Cubic Foot of Dry Air.	Temp. Fahr.	Weight of a Cubic Foot of Dry Air.	Temp. Fahr.	Weight of a Cubic Foot of Dry Air.	Temp. Fahr.	Weight of a Cubic Foot of Dry Air.
°	grs.	°	grs.	°	grs.	°	grs.
0	606·37	26	573·87	51	545·74	76	520·25
1	605·05	27	572·69	52	544·67	77	519·28
2	603·74	28	571·51	53	543·61	78	518·31
3	602·43	29	570·34	54	542·55	79	517·35
4	601·13	30	569·17	55	541·50	80	516·39
5	599·83	31	568·01	56	540·45	81	515·43
6	598·54	32	566·85	57	539·40	82	514·48
7	597·26	33	565·70	58	538·36	83	513·53
8	595·98	34	564·56	59	537·32	84	512·59
9	594·71	35	563·42	60	536·28	85	511·65
10	593·44	36	562·28	61	535·25	86	510·71
11	592·18	37	561·15	62	534·22	87	509·77
12	590·92	38	560·02	63	533·20	88	508·84
13	589·67	39	558·89	64	532·18	89	507·91
14	588·42	40	557·77	65	531·17	90	506·99
15	587·18	41	556·66	66	530·16	91	506·07
16	585·95	42	555·55	67	529·15	92	505·15
17	584·72	43	554·44	68	528·14	93	504·23
18	583·49	44	553·34	69	527·14	94	503·32
19	582·27	45	552·24	70	526·15	95	502·41
20	581·05	46	551·15	71	525·16	96	501·50
21	579·84	47	550·06	72	524·17	97	500·60
22	578·64	48	548·97	73	523·18	98	499·70
23	577·44	49	547·89	74	522·20	99	498·81
24	576·24	50	546·82	75	521·22	100	497·93
25	575·05						

SECTION IV.

RAIN.

Rain is estimated in inches; that is, the fall of an inch of rain implies that on any given area, say a square inch of surface, rain has fallen equal to one inch in depth. The amount of rain is determined by a rain-gauge. Two gauges are supplied for military stations; one placed on the ground, one 20 feet above it; in all parts of the world the latter indicates less rain than the lower placed gauge.*

Several kinds of gauges are in use. The one used by the Army Medical Department is a round tin box with a rim or groove at the top; a round top with a funnel inside fits on to this groove, which, when filled with water, forms a water valve. The opening above is circular (the circle being made very carefully, and a rim being carried round it to prevent the rain-drops from being whirled by wind out of the mouth), and descends funnel-shaped, the

* Serjeant Arnold, of the Army Hospital Corps, who is an excellent meteorologist, has accumulated evidence to show that this is merely an effect of wind. When the upper rain-gauge is inclined at a certain angle with the wind, there is as much rain above as below.

small end of the funnel being turned up to prevent evaporation. The best size for the open top, or in other words, the area of the receiving surface, is about 100 square inches. The lower part of the box is sunk in the ground nearly to the groove; the upper part is then put in, and a glass vessel is placed below the funnel to receive the water. At stated times (usually at 9 A.M. daily) the top is taken off, the glass vessel taken out, and the water weighed or measured. The latter is easiest, and is done in a glass vessel graduated to an inch and hundredths of an inch, and which is sent with the gauge. Each gauge has its own measure.

If this glass is broken it can be replaced by the following rule, or a rain-gauge can be made by any one very easily. It need not be round, though this is now thought the best form, but may be a square box of metal or wood, and may be of any size near a square foot; the small gauges are not to be trusted, and the large are unwieldy.

Determine the area, in square inches, of the receiving surface, or top of the gauge, by careful measurement (see Measurement of Rooms, chapter on AIR). This area, if covered with water to the height of one inch, would give us a corresponding amount of cubic inches. This number of cubic inches is the measure of that gauge for one inch, because when the rain equals that quantity it shows that one inch of rain has fallen over the whole surface.

Let us say the area of the receiving surface is 100 square inches. Take 100 cubic inches of water and put it into a glass, put a mark at the height of the fluid, and divide the glass below it into 100 equal parts. If the rainfall comes up to the mark, one inch of rain has fallen on each square inch of surface; if it only comes up to a mark below, some amount less than an inch (which is so expressed in $\frac{1}{10}$ths and $\frac{1}{100}$ths) has fallen.

To get the requisite number of cubic inches of water we can weigh or measure. A cubic inch of water at 62° weighs 252·458 grains, consequently 100 cubic inches will be $(252{\cdot}458 \times 100) = 25245{\cdot}8$ grains, or 57·7 ounces avoir. But an easier way still is to measure the water,—an ounce avoir. is equal to 1·733 cubic inches, therefore divide 100 by 1·733, and we obtain the number of ounces avoir. which corresponds to 100 cubic inches.

Usually a one-inch measure is so large a glass, that half an inch is considered more convenient.

From the table of the weight of vapour already given, it will be seen that the amount of vapour which can be rendered insensible, increases with the temperature, but not regularly; more, comparatively, is taken up by the high temperatures; thus, at 40°, 2·86 grains are supported; at 50°, 4·10 grains, or 1·24 grains more; at 60°, 5·77 grains, or 1·67 grains more than at 50.° Therefore, if two currents of air of unequal temperatures, but equally saturated with moisture, meet in equal volume, the temperature will be the mean of the two, but the amount of vapour which will be kept invisible is less than the mean, and some vapour therefore necessarily falls as fog or rain. Thus one saturated current being at 40°, and the other at 60°, the resultant temperature will be 50°, but the amount of invisible vapour will not be the mean, viz., 4·315, but 4·1; an amount equal to ·215 will therefore be deposited.

Rain is therefore owing to the cooling of a saturated air, and rain is heaviest under the following conditions,—when the temperature being high, and the amount of vapour large, the hot and moist air soon encounters a cold air. These conditions are chiefly met with in the tropics, when the hot air, saturated with vapour, impinges on a chain of lofty hills over which the air is cold. The fall may be 130 to 160 inches, as on the Malabar coast of India, or 180 to 220 in Southern Burmah, or 600 at Cherrapoonjee, in the Khasyah Hills. Even in our own country the hot air from the Gulf Stream

impinging on the Cumberland Hills causes, in some districts a fall of 80, 100, and even 130 inches.

The rainfall in different places is remarkably irregular from year to year; thus at Bombay the mean being 76, in 1822 no less than 112 inches, while in 1824 only 34 inches fell.

The amount of rain in the different foreign stations is given under the respective headings.

SECTION V.

EVAPORATION.

The amount of evaporation from a given moist surface is a problem of great interest, but it is not easy to determine it experimentally, and no instrument is issued by the Army Medical Department. A shallow vessel of known area, protected round the rim by wire to prevent birds from drinking, is filled with a known quantity of water, and then, weekly or monthly, the diminution of the water is determined, the amount of addition by rain being at the same time determined by a rain-gauge. This plan takes no notice of dew, and is not regarded as satisfactory.

Another plan is placing water under a cover, which may protect it from rain and dew, and yet permit evaporation, and weighing the loss daily. It is difficult, however, to ensure that the evaporation shall be equal to that under the free heavens.

A third plan is calculating the rate of evaporation from the depression of the wet-bulb thermometer, by deducting the elastic force of vapour at the dew-point temperature from the elastic force at the air temperature, and taking the difference as expressing the evaporation. This difference expresses the force of escape of vapour from the moist surface.

Instruments termed Atmometers have been used for this purpose; the first was invented by Leslie. A ball of porous earthenware was fixed to a glass tube, with divisions, each corresponding to an amount of water which would cover the surface of the ball with a film equal to the thickness of $\frac{1}{1000}$th part of an inch. The evaporation from the surface of the ball was then read off. Dr Babington has also invented an ingenious "Atmidometer."*

The amount of evaporation is influenced by temperature, wind, humidity of the air, rarefaction of the air, degree of exposure or shading, and by the nature of the moist surface; it is greater from moist soil than from water.

The amount of vapour annually rising from each square inch of water surface in this country has been estimated at from 20 to 24 inches; in the tropical seas it has been estimated at from 80 to 130, or even more inches. In the Indian Ocean it has been estimated at as much as an inch in twenty-four hours, or 365 in the year, an almost incredible amount. No doubt, however, the quantity is very great.

It requires an effort of imagination to realise the immense distillation which goes on from the tropical seas. Take merely 60 inches as the annual distillation, and reckon this in feet instead of inches, and then proceed to calculate the weight of the water rising annually from such a small space as the Bay of Bengal. The amount is almost incredible.

This distillation of water serves many great purposes; mixing with the air it is a vast motive power, for its specific gravity is very low (·6235, air being 1), and it causes an enlargement of the volume of air; the moist air is therefore much lighter, and ascends with great rapidity; the distillation also causes an immense transference of heat from the tropics, where the evaporation renders

* See Negretti and Zambra's Treatise, p. 141, for details.

latent a great amount of heat, to the extra-tropical region where this vapour falls as rain, and consequently parts with its heat. The evaporation also has been supposed to be a great cause of the ocean currents (Maury), which play so important a part in the distribution of winds, moisture, and warmth.

For physicians the amount of evaporation is a very important point, not merely as influencing the moisture of the air abstractedly, but as affecting the evaporation from the skin and lungs. The evaporating power of the air is inversely to its relative humidity in a still air; it is of course influenced by winds and their temperature, and the vessels and the nerves of the skin are then affected, and evaporation may be accelerated by the physical conditions of motion and warmth, or may be lessened by the physiological action of the wind. The problem is thus a complicated one. (See CLIMATE.)

SECTION VI.

WIND.

Direction.—For determining the direction of the wind a vane is necessary. It should be placed in such a position as to be able to feel the influence of the wind on all sides, and not be subjected to eddies by the vicinity of buildings, trees, or hills. The points must be fixed by the compass; the magnetic declination being taken into account; the declination of the place must be obtained from the nearest Observatory; in this country it is now about 21° to the westward of true north. The direction of the wind is registered twice daily in the army returns, but any unusual shifting should receive a special note. The course of the wind is not always parallel with the earth; it sometimes blows slightly downwards; contrivances have been employed to measure this, but it does not seem important.

Various plans are resorted to for giving a complete summary of the winds, but these are not required from the medical officer.

Velocity.—A small Robinson's anemometer is now supplied to each station; it is read every twenty-four hours, and marks the horizontal movement in the preceding twenty-four hours.

This anemometer usually consists of four small cups,* fixed on horizontal axes of such a length (1·12 feet between two cups), that the centre of a cup, in revolving a circle, passes over $\frac{1}{1500}$th of a mile; or the distance between two cups is exactly one foot, so that the circle is 3·1416 feet. These cups revolve with a third of the wind's velocity; 500 revolutions of the cups therefore indicate one mile. By an arrangement of wheels, the number of miles traversed by the cups in any given time is registered.

This instrument should be made also to register the maximum velocity at any time.

Osler's anemometer is a larger and very beautiful instrument. It registers at the same time on a piece of paper fitted on a drum, which turns with clock-work, direction, velocity, and pressure.

Other anemometers, Lind's, Whewell's, &c., need not be described.

The average velocity of wind in this country on the surface of the earth is from six to eight miles per hour; its range is from zero to 60 or even 70 miles per hour, but this last is very rare; it is seldom more, even in heavy winds, than 35 to 45 miles per hour. In the hurricanes of the Indian and China seas it is said to reach 100 to 110 miles per hour.

Force.—The force of the wind is reckoned as equal to so many pounds or

* The current of air is opposed one-fourth more by a concave surface than by a convex one of the same size.

parts of a pound on a square foot of surface. Osler's anemometer registers the force as well as the velocity and direction, but Robinson's (used in the army) only marks the velocity; the force must then be calculated. The rule for the calculation of the force from the velocity is as follows:—*

Ascertain the velocity for one hour by observing the velocity for a minute, and multiplying by 60; then square the hour velocity and multiply by ·005. The result is the pressure in pounds or parts of a pound per square foot.

$$V^2 \times .005 - P.$$

The subjoined table is taken from Sir Henry James's work, and will save the trouble of calculating:—

Pressure in lbs per Square Foot.	Velocity in Miles per Hour.	Pressure in lbs per Square Foot.	Velocity in Miles per Hour.	Pressure in lbs per Square Foot.	Velocity in Miles per Hour.	Pressure in lbs per Square Foot.	Velocity in Miles per Hour.	Pressure in lbs per Square Foot.	Velocity in Miles per Hour.
oz.		lbs		lbs		lbs		lbs	
0·08	1·000	4·25	29·154	12·50	50·000	20·75	64·420	29·00	76·157
0·25	1·767	4·50	30·000	12·75	50·497	21·00	64·807	29·25	76·485
0·50	2·500	4·75	30·822	13·00	50·990	21·25	65·192	29·50	76·811
0·75	3·061	5·00	31·622	13·25	51·478	21·50	65·574	29·75	77·136
1·00	3·535	5·25	32·403	13·50	51·961	21·75	65·954	30·00	77·459
2·00	5·000	5·50	33·166	13·75	52·440	22·00	66·332	30·25	77·781
3·00	6·123	5·75	33·911	14·00	52·915	22·25	66·708	30·50	78·102
4·00	7·071	6·00	34·641	14·25	53·385	22·50	67·082	30·75	78·421
5·00	7·905	6·25	35·355	14·50	53·851	22·75	67·453	31·00	78·740
6·00	8·660	6·50	36·055	14·75	54·313	23·00	67·823	31·25	79·056
7·00	9·354	6·75	36·742	15·00	54·772	23·25	68·190	31·50	79·372
8·00	10·000	7·00	37·416	15·25	55·226	23·50	68·556	31·75	79·686
9·00	10·606	7·25	38·078	15·50	55·677	23·75	68·920	32·00	80·000
10·00	11·180	7·50	38·729	15·75	56·124	24·00	69·282	32·25	80·311
11·00	11·726	7·75	39·370	16·00	56·568	24·25	69·641	32·50	80·622
12·00	12·247	8·00	40·000	16·25	57·008	24·50	70·000	32·75	80·932
13·00	12·747	8·25	40·620	16·50	57·445	24·75	70·356	33·00	81·240
14·00	13·228	8·50	41·231	16·75	57·879	25·00	70·710	33·25	81·547
15·00	13·693	8·75	41·833	17·00	58·309	25·25	71·063	33·50	81·853
lbs		9·00	42·426	17·25	58·736	25·50	71·414	33·75	82·158
1·00	14·142	9·25	43·011	17·50	59·160	25·75	71·763	34·00	82·462
1·25	15·811	9·50	43·588	17·75	59·581	26·00	72·111	34·25	82·764
1·50	17·320	9·75	44·158	18·00	60·000	26·25	72·456	34·50	83·066
1·75	18·708	10·00	44·721	18·25	60·415	26·50	72·801	34·75	83·366
2·00	20·000	10·25	45·276	18·50	60·827	26·75	73·143	35·00	83·666
2·25	21·213	10·50	45·825	18·75	61·237	27·00	73·484	35·25	83·964
2·50	22·360	10·75	46·368	19·00	61·644	27·25	73·824	35·50	84·261
2·75	23·452	11·00	46·904	19·25	62·048	27·50	74·161	35·75	84·567
3·00	24·494	11·25	47·434	19·50	62·449	27·75	74·498	36·00	84·852
3·25	25·495	11·50	47·958	19·75	62·849	28·00	74·833	36·25	85·146
3·50	26·457	11·75	48·476	20·00	63·245	28·25	75·166	36·50	85·440
3·75	27·386	12·00	48·989	20·25	63·639	28·50	75·498	36·75	85·732
4·00	28·284	12·25	49·497	20·50	64·031	28·75	75·828	37·00	86·023

* The velocity can be calculated from the pressure by taking the square root of 200 times the pressure, or

$$\sqrt{200 \times P} = V.$$

SECTION VII.

CLOUDS.

The nomenclature proposed by Howard* is now universally adopted. There are three principal forms and four modifications.

Principal Forms.

Cirrus.—Thin filaments, which by association form a brush, or woolly hair, or a slender net-work. They are very high in the atmosphere, probably more than ten miles, but the exact height is unknown. It has even been questioned whether they are composed of water; if so, it must be frozen. In this climate they come from the south-west.

Cumulus.—Hemispherical or conical heaps like mountains rising from a horizontal base; cumuli are often compared to balls of cotton.

Stratus.—A widely-extended, continuous, horizontal sheet, often forming at sunset.

Modifications.

Cirro-cumulus.—Small rounded, well-defined masses, in close, horizontal arrangement; when the sky is covered with such clouds it is said to be fleecy.

Cirro-stratus.—Horizontal strata or masses, more compact than the cirri; at the zenith they seem composed of a number of thin clouds; at the horizon they look like a long narrow band.

Cumulo-stratus.—Cirro-stratus blended with the cumulus.

Cumulo-cirro-stratus or Rain-cloud.—A horizontal sheet above which the cirrus spreads, while the cumulus enters it laterally or from below.

Estimation of Amount of Cloud.—This is done by a system of numbers—1 expresses a cloudless sky, 10 a perfectly clouded sky, the intermediate numbers various degrees of cloudiness. To get these numbers, look midway between the horizon and zenith, and then turn slowly round, and judge as well as can be done of the relative amount of clear and clouded sky.

SECTION VIII.

OZONE.

Papers covered with a composition of iodide of potassium and starch, and exposed to the air, are supposed to indicate the amount of ozone present in the atmosphere. Schönbein, the discoverer of ozone, originally prepared such papers, and gave a scale by which the depth of blue tint was estimated. Subsequently similar but more sensitive papers were prepared by Dr Moffat, and lately Mr Lowe has improved Moffat's papers, and has also prepared some ozone powders.

The papers are exposed for a definite time to the air, if possible with the exclusion of light, and the alteration of colour is compared with a scale.

Schönbein's proportions are—1 part of *pure* iodide of potassium, 10 parts starch, and 200 parts of water. Lowe's proportion is 1 part of iodide to 5 of starch. The starch should be dissolved in cold water, and filtered so that a clear solution is obtained; the iodide is dissolved in another portion of water, and is gradually added.

The paper prepared by being cut into slips (so as to dry quicker and to

* Climate of London.

avoid loss of the powder in cutting) and soaked in distilled water, is placed in the mixed iodide and starch for four or five hours, then removed with a pair of pincers, and slowly dried in a cool dark place in a horizontal position. The last point is important, as otherwise a large amount of the iodide drains down to one end of the paper, and it is not equally diffused. The papers when used should hang loose in a box, the bottom of which is removed; they must not touch or rub against the box, or against each other, if more than one is hanging; they should not be touched more than can be helped with the fingers when they are adjusted.

When Schönbein's papers are used they are moistened with water after exposure, but before the tint is taken. Moffat's papers are prepared somewhat similarly to Schönbein's, but do not require moistening with water. Mr Lowe has lately prepared some very sensitive papers which give very uniform results.

The estimation of ozone is still in a very unsatisfactory state, and this arises from two circumstances.

1. The fact that other substances besides ozone act on the iodide of potassium, especially nitrous acid, which is formed in some quantity during electrical storms. Cloez has shown that air taken about one metre above the ground often contains nitrous acid in sufficient quantity to redden litmus. Starch and iodide paper is coloured when air contains ·00005 of its volume of nitrous acid. Indeed some chemists have doubted whether any proof has even yet been given of the presence of ozone in the atmosphere (Frankland).

2. The fact that the papers can scarcely be put under the same conditions from day to day; light, wind, humidity, and temperature (by expelling the free iodine) all effect the reaction.

Two chemical objections have also been made.* Supposing that iodine is set free by ozone, a portion of it is at once changed by additional ozone into iodozone, which is extremely volatile at ordinary temperatures, and is also changed by contact with water into free iodine and iodic acid. Hence a portion of the iodine originally set free never acts on the starch, being either volatilised or oxidised. Again the ozone may possibly, and probably, act on the starch itself, and hence another error.

In spite of these difficulties it seems desirable to continue the ozone observations; they must have a value, and the investigation will perhaps bring its own interpretation. But, at present, we ought to be cautious in drawing conclusions from any ozonometric experiments.

Dr Lankester has contrived a self-registering ozonometer; an inch of prepared paper passes per hour by clock-work beneath an opening in the cover. The paper, however, would have to be still exposed to air in the box, unless means were taken for fixing the tint.

SECTION IX.

ELECTRICITY.

At present the Army Medical Department has not organised any system of electrical observations. Eventually, probably, electrical phenomena will be observed and recorded.

The instruments used by meteorologists are simple electroscopes, with two gold-leaf pieces which diverge when excited, or dry galvanic piles acting on gold-leaf plates or an index attached to a Leyden jar (Thomson's Electrometer).

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* Beitrage zur Ozonometrie, von Dr v. Maach; Archiv. für Wiss. Heilk. band ii. p. 29.

SECTION X.

THERMOMETER STAND.

A stand is issued by the War-office, and will be provided at every station. Or it would be very easy to make a stand by two or three strata of boards, placed about 6 inches apart, so as to form a kind of sloping roof over the thermometers, which are suspended on a vertical board.

The dry and wet bulb thermometers are placed in the centre; the maximum on the right side, and the minimum on the left. The wood should be cut away behind the bulbs of the maximum and minimum thermometers, so as to expose them freely to the air. The bulbs of the dry and wet bulbs should also fall below the board.

In the regular stands, the pole is made to rotate, so as to turn the roof always to the sun; but if there is any difficulty in doing this, projecting pieces of wood can easily be arranged to keep the sun's rays from falling on the thermometers.

SECTION XI.

DISEASES AND VARIATIONS IN THE METEOROLOGICAL ELEMENTS.

The variation in the prevalence of different diseases at a particular place, in connection with the simultaneous variation of meteorological elements, is an old inquiry which has at present led to few results. The reason of this is, that the meteorological elements are only a few out of a great many causes affecting the prevalence and severity of diseases. Consequently, in order to estimate the real value of changes of temperature, pressure, humidity, ozone, &c., the other causes of disease, or of variations in prevalence or intensity, must be recognised and eliminated from the inquiry; then the action *per se* of the different meteorological conditions will be apparent. The subject at present is more fitted for a work on the practice of medicine than for one on hygiene. The best of the late observations are those by Guy, Ransome, Vernon, Moffat, Tripe, Scoresby-Jackson, and Ballard.* The observations of the last-named observer are very elaborate and careful, but I hesitate to cite them as certain until they are confirmed. They indicate a rise in the amount of sickness with a rise in temperature, but that certain supplementary meteorological conditions (such as the temperature of the night, the daily range, variations in humidity, rainfall, direction of wind), all affect the result. The amount of previous change in the amount of sickness also influences, and in fact it is evident that the problem is in a high degree complicated.

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* Medico-Chirurgical Transactions, vol. l.

CHAPTER XVII.

CLIMATE.

It is not easy to give a proper definition of climate. The effect of climate on the human body is the sum of the influences which are connected either with the solar influences, the soil, the air, or the water of a place, and as these influences are in the highest degree complex, it is not at present possible to trace out their effects with any certainty.

With regard generally to the effect of climate on human life, it would seem certain that the facility of obtaining food (which is itself influenced by climate), rather than any of the immediate effects of climate, regulates the location of men and the amount of population. The human frame seems to acquire in time a wonderful power of adaptation; the Esquimaux, when they can obtain plenty of food, are large strong men (though nothing is known of their average length of life), and the dwellers in the hottest parts of the world (provided there is no malaria, and that their food is nutritious) show a stature as lofty, and a strength as great, as any dwellers in temperate climates. Peculiarities of race, indeed, arising no one knows how, but probably from the combined influences of climate, food, and customs, acting through many ages, appear to have more effect on stature, health, and duration of life, than climate alone. Still, it would seem probable that, in climatic conditions so diverse, there arise some special differences of structure which are most marked in the skin, but may possibly involve other organs.

How soon the body, when it has become accustomed by length of residence for successive generations to one climate, can accommodate itself to, or bear the conditions of, the climate of another widely different place, is a question which can only be answered when the influences of climate are better known. The hypothesis of "acclimatisation" implies that there is at first an injurious effect produced, and then an accommodation of the body to the new conditions within a very limited time; that, for example, the dweller in northern zones passing into the tropics, although he at first suffers, acquires in a few years some special constitution which relieves him from the injurious consequences which, it is supposed, the change at first brought with it. There are, therefore, two assumptions, viz., of an injurious effect, and of a relief from it. Are either correct?

It may seem a bold thing to question the commonly received opinion, that a tropical climate is injurious to a northern constitution, but there are some striking facts which it is difficult to reconcile with such an opinion. The army experience shows that, both in the West Indies and in India, the mortality of the soldier has been gradually decreasing, until, in some stations in the West Indies (as, for example, Trinidad and Barbadoes), the sickness and mortality among the European soldiers are actually less than on home service, in years which have no yellow fever. In India, a century ago, people spoke with horror of the terrible climate of Bombay and Calcutta.

and yet Europeans now live in health and comfort in both cities. In Algeria the French experience is to the same effect. As the climate and the stations are the same, and the soldiers are of the same race and habits, what has removed the dangers which formerly made the sickness threefold and the mortality tenfold the ratio of the sickness and deaths at home?

The explanation is very simple; the deaths in the West Indies were partly owing to the virulence of yellow fever (which was fostered, though probably not engendered by bad sanitary conditions), and the general excess of other febrile and dysenteric cases. The simple hygienic precautions which are efficacious in England have been as useful in the West Indies. Proper food, good water, pure air, have been supplied, and, in proportion as they have been so, the deadly effects attributed to climate have disappeared. The effect of a tropical climate is, so to speak, relative. The temperature and the humidity of the air are highly favourable to decomposition of all kinds; the effluvia from an impure soil, the putrescent changes going on in it are greatly aggravated by heat. The effects of the sanitary evils which, in a cold climate like Canada, are partly neutralised by the cold, in the West Indies, or in tropical India, are developed to the greatest degree. In this way a tropical climate is evidently most powerful, and it renders all sanitary precautions tenfold more necessary than in the temperate zone. But all this is not the effect of climate, but of something added to climate.

Take away these sanitary defects, and avoid malarious soils (or drain them, as the French have done with wonderful success in one of the worst stations, Boufaric, in Algeria), and let the mode of living be a proper one, and the European soldier does not die faster in the tropics than at home.*

It must be said, however, that an element of uncertainty may be pointed out here. In our tropical possessions the European soldier serves now only for short periods (in the West Indies for three or four years, in India only for twelve years), and during this time he may be for some years on the hills, or at any rate in elevated spots. The old statistical reports of the army pointed out that the mortality in the West Indies augmented regularly with prolongation of service, and it may be said that, after all, the lessened sickness and mortality in the tropics is owing, in some degree, to avoidance by short service of the influences of climate. But as the old long service was constantly passed under the unfavourable sanitary conditions now removed, it does not follow that the inference to be drawn from the statistical evidence as to length of service is really correct.

Facts prove, then, that under favourable sanitary conditions (general and personal), Europeans, during short services, may be as healthy as at home, as far as shown by tables of sickness and mortality,† and it is not certain that long service brings with it different results.

It may, however, be argued that, admitting that a non-malarious tropical climate *per se*, may not increase sickness or mortality during the most vigorous years of life (and it is then only that Europeans are usually subjected to it), it may yet really diminish health, lessen the vigour of the body, and diminish the expectation of life.

We have no evidence on the latter point.‡ With respect to the former,

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* The production of liver disease in such an amount in India, will be considered by some to be a pure effect of climate. But on this point the evidence seems to me to point most strongly in another direction (see chapter on the Prevention of Disease).

† For the statistical proofs see the chapters on the West Indies and India.

‡ The tables of the Indian Sanitary Commission, as applying to men who had been under the unfavourable sanitary conditions which prevailed more or less in India till within the last few years, can hardly be used with safety to settle this point.

it will be well to see what is known of the effects of climatic agencies on the frame.

The influences of locality and climate, as far as they are connected with soil and water, have been sufficiently discussed. I shall merely briefly review the climatic conditions most closely (though by no means solely) connected with air. They are—temperature, humidity, movement, weight, composition, and electrical condition. . The amount of light is another climatic condition of importance.

SECTION I.

I. TEMPERATURE.*

The amount of the sun's rays; the mean temperature of the air; the variations in temperature, both periodic and non-periodic; and the length of time a high or low temperature lasts, are the most important points. Temperature alone has been made a ground of classification of climate.

(*a.*) Equable, limited, or insular climates; *i.e.*, with slight yearly and diurnal variations.

(*b.*) Extreme, excessive, or continental; *i.e.*, with great variations.

The terms limited and extreme might be applied to the amplitude of the yearly fluctuation (*i.e.*, difference between hottest and coldest month, see METEOROLOGY), while equable and excessive might be applied especially to the non-periodic variations, which are slight in some places, and extreme in others.

A limited climate is generally an equable one, and an extreme climate (with great yearly fluctuation) is generally an excessive one (with great undulations).

The effects of heat cannot be dissociated from the other conditions; it is necessary, however, to briefly notice them.

The effect of a certain degree of temperature on the vital processes of a race dwelling generation after generation on the same spot, is a question which has yet received no sort of answer. Does the amount of heat *per se*, independent of food and all other conditions, affect the development of mechanical force and temperature, and the coincident various processes of formation and destruction of the tissues? Is there a difference in these respects, and in the resulting action of the eliminating organs, in the inhabitants of the equator and of 50° or 60° N. lat? This is entirely a problem for the future, but there is no class of men who have more opportunities of studying it than the army surgeons.

The problem of the influence of temperature is generally presented to us under the form of a dweller in a temperate zone proceeding to countries either colder or hotter than his own. It is in this restricted sense I shall now consider it.

With regard to the effect on the Anglo-Saxon and Celtic races of going to live in a climate with a lower mean temperature and greater variations than their own, we have the experience of Canada, Nova Scotia, and some parts of the Northern American States. In all these, if food is good and plentiful, health is not only sustained, but is perhaps improved. The agricultural and out-door life of Canada or Nova Scotia is probably the cause of this; but certain it is that in those countries the European not only enjoys health, but produces a progeny as vigorous, if not more so, than that of the parent race.

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* For some elementary facts on temperature see METEOROLOGY.

The effects of heat exceeding the temperate standard must be distinguished according to its origin; radiant heat, or the direct rays of the sun, and non-radiant heat, or that of the atmosphere. In the latter case, in addition to heat there is more or less rarefaction of the air, and also coincident conditions of humidity and movement of the air, which must be taken into account. The influence, again, of sudden transitions from heat to cold, or the reverse, has to be considered. The Europeans from temperate climates flourish, apparently, in countries not much hotter than their own, as in some parts of Australia, New Zealand, and New Caledonia, though it is yet too soon to speculate whether the vigour of the race will improve or otherwise. But there is a general impression that they do not flourish in countries much hotter, *i.e.*, with a yearly mean of 20° Fahr. higher, as in many parts of India; that the race dwindles, and finally dies out; and therefore that no acclimatisation of race occurs. And certainly it would appear that, in India and in the West Indies, sickness and mortality increase with length of residence, and there is some evidence to show that the pure race, if not intermixed with the native, does not reach beyond the third generation. Yet it seems only right to say that so many circumstances besides heat and the other elements of climate have been acting on the English race in India, that any conclusion opposed to acclimatisation must be considered as based on scanty evidence. We have not gauged on a large scale the effect of climate pure and simple, uncomplicated with malaria, bad diet, and other influences adverse to health and longevity.*

(*a.*) *Influence of the Direct Rays of the Sun.*—It is not yet known to what temperature the direct rays of the tropical sun can raise any object on which they fall. In India, on the ground, the uncovered thermometer will mark 160°, and perhaps 212° (Buist); and in this country, if the movement of air is stopped in a small space, the heat in the direct sun's rays can be raised to the same point. In a hermetically sealed box, with a glass top, Sir H. James found the thermometer mark 237° Fahr., when exposed to the rays of the sun, on the 14th July 1864. In experiments on frogs, when a temperature much over the natural amount is applied to nerves, the electrical currents through them are lessened, and at last stop.† E. H. Weber's observations show that for men the same rule holds good; the most favourable temperature is 30° R. (= 99°·5 Fahr).‡ It appears also from Kühne's experiments that the heat of the blood of the vertebrata must not exceed 113° Fahr., for at that temperature one of the albuminous bodies in muscles coagulates. (Ludwig, *Lehrb. der Phys.* band ii. p. 732.) Perhaps this fact may be connected with the pathological indication that a very high temperature in any disease (over 110° Fahr.) indicates the extremest danger.

To what temperature is the skin of the head and neck raised in the tropics in the sun's rays? No sufficient experiments have, I believe, been made, either on this point or on the heat in the interior of caps and hats with and without ventilation. Doubtless, without ventilation, the heat above the head in the interior of a cap is very great. It is quite possible, as usually assumed, that with bad head-dresses the heat of the skin, bones, and possibly even of the deep nerves and centres (the brain and cord), may be greater than is accordant with perfect preservation of the currents of the nerves, or of the

* In India the mortality of Eurasians (that is, the mixed race of British, Portuguese, Hindoo, Malay, blood mixed in all degrees) appears to be below that of the most healthy European service, viz., the Civil Service. Mr Tait's facts (On the Mortality of Eurasians; "Statistical Journal," September 1864) would show that this mixed race will maintain itself in India.

† Eckhard, Henle's Zeitsch. band x. p. 165, 1851.

‡ Weber, Ludwig's Phys., 2d ed. vol. i. p. 126.

necessary temperature of the blood, or with the proper fluidity of some of the albuminous bodies in the muscles.

The difficulty of estimating the exact effect of the solar rays is not only caused by the absence of a sufficient number of experiments, but by the common presence of other conditions, such as a hot, rarefied, and perhaps impure air, and heat of the body produced by exercise, which is not attended by perspiration. Two points are remarkable in the history of sun-stroke, viz., the extreme rarity of sun-stroke in mid-ocean,* and at great elevations. In both cases the effect of the sun's rays, *per se,* is not less, is even greater, than on land and at sea-level; yet in both sun-stroke is uncommon; the temperature of the air, however, is never excessive in either case.

The effect of the direct rays on the skin is another matter requiring investigation. Does it aid or check perspiration? That the skin gets dry there is no doubt, but this may be merely from rapid evaporation. But if the nervous currents are interfered with, the vessels and the amount of secretion are sure to be affected, and on the whole it seems probable that a physiological effect adverse to perspiration is produced by the direct rays of the sun. If so, and if this is carried to a certain point, the heat of the body must rise, and supposing the same conditions to continue (intense radiant heat and want of perspiration), may pass beyond the limit of the temperature of possible life (113° Fahr.)

The effect of intense radiant heat on the respiration and heart is another point of great moment which needs investigation.

The pathological effects produced by the too intense direct rays of the sun are supposed to be one form of insolation.

A form of fever (the *Causus* of some writers) has been supposed to be caused by the direct rays of the sun combined with excessive exertion. I have seen a case of this kind which corresponded closely to the description in books. The fever lasted for several days, and its type was not in accordance with the hypothesis that it was malarious fever, or febricula, or typhoid. No thermometric observations were made on the patient.

(*b.*) *Heat in Shade.*—The effect of high air temperature on the native of a temperate climate passing into the tropics has not been very well determined, and some of the conclusions are drawn from experiments on animals exposed to an artificial temperature.

1. The temperature of the body does not rise greatly—not more than ·5 or 1° Fahr. (John Davy); from 1° to 2½° and 3° (Eydaux and Brown Sequard). The temperature of the body is the result of the opposing action of two factors —1*st*, of development of heat from the chemical changes of the food, and by the conversion of mechanical force into heat, or by direct absorption from without; and, 2*d*, and opposed to this, of evaporation from the surface of the body, which regulates internal heat. So beautifully is this balance preserved, that the stability of the animal temperature in all countries has always been a subject of marvel. If anything, however, prevents this evaporation, radiation and the cooling effect of moving wind cannot cool the body sufficiently in the tropics. Then, no doubt, the temperature of the body rises, especially if in addition there is muscular exertion and production of heat from that cause. The extreme discomfort always attending abnormal heat of body then commences. Thermometric observations in the tropics on this point are much needed. In experiments in ovens, Blagden and Fordyce bore a temperature of 260° with a small rise of temperature (2½° Fahr.), but the air was dry, and the heat of their bodies was reduced by perspiration; when the air in ovens

* The cases of insolation in a narrow sea like the Red Sea do not invalidate this rule.

is very moist and evaporation is hindered, the temperature of the body rises rapidly.*

2. The respirations are lessened in number (Vierordt, Ludwig) in animals subjected to heat, and the same is believed to hold good in the tropics. According to Vierordt, less carbonic acid and presumably less water are eliminated.

Dr Francis (Bengal Army) has lately observed that the lungs are lighter after death in Europeans in India than the European standard. I made a similar observation many years ago, and noticed it in a work on cholera, but had not sufficient facts to enable me to be quite certain. If Dr Francis' statement be confirmed, it would show apparently a diminished respiratory function.

3. The heart's action is somewhat increased in frequency, perhaps not in force, in new comers, in tropical climates. In experiments on animals, moderate heat does not quicken the heart, but great heat does.

4. The digestive powers are somewhat lessened, there is less appetite, less desire for animal food, and more wish for cool fruits. The quantity of bile secreted by the liver is not increased, if the stools are to be taken as a guide (Marshall, in 1819, John Davy, Morehead, author), though Lawson believes that an excess of colouring matter passes out with the stools; nothing is known of the condition of the usual liver work.

5. The skin acts much more than usual, and great local hyperæmia and swelling of the papillæ occur in new comers, giving rise to the familiar eruption known as "prickly heat." In process of time, if exposed to great heat, the skin suffers apparently in its structure, becoming of a slight yellowish colour from, probably, pigmentary deposits in the deep layers of the cuticle.

6. The urine is lessened in quantity. The urea is lessened, as shown by experiments in hot seasons at home and during voyages (Dr Forbes Watson and Dr Becher).† It is not yet certain whether this is simply from lessened food. The pigment has been supposed to be increased (Lawson), but this is doubtful. The chloride of sodium is lessened; the amount of uric and phosphoric acids is uncertain.

7. The effect on the nervous system is generally considered as depressing and exhausting, *i.e.*, there is less general vigour of mind and body. But it is undoubted that the greatest exertions both of mind and body have been made by Europeans in hot climates. Robert Jackson thought as much work could be got of men in hot as in temperate climates. It is probable that the depressing effects of heat are most felt when it is combined with great humidity

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* Even 7° to 8° Fahr. (Ludwig, "Lehrb. der Phys.," 2d edit. b. ii. p. 730.) Obernier's late observations are confirmatory (Der Hitzschlag, Bonn, 1867). Obernier confirms the pathology generally received in this country. From an observation of four cases of sunstroke, and from thirty-three experiments on animals exposed to artificial heat, he traces all the effects to the augmented temperature of the body, which cannot cool by evaporation from the surface and lungs as usual. He puts down as necessary conditions, a high external temperature, internal conditions, as of marching, running, which augment bodily heat, and the absence of water. He does not, however, deny that there may be also a direct alteration of the nervous tissue by the heat (p. 96). He noticed in two cases in men some amount of urea in the blood, but he did not find this in animals. He distinguishes two forms of sunstroke: asthenic, where the elevation of the temperature of the body brings on early collapse; and sthenic, where the bodily temperature attains a great height, and then suddenly the attack comes on with more or less reaction. In the one case there is a pale face and a copious sweating and cold skin (this is the heat asphyxia of some authors), in the other there is the red face, the injected eyes, the sobbing, breathing, convulsions, delirium, &c.

† These experiments are not yet fully published; they were made during voyages to Bombay and China, and show that when the temperature reached a certain point (75° in Dr Becher's experiments), the solids of the urine and the urea lessened considerably.—*Proceedings of the Royal Society*, 1862.

of the atmosphere, so that evaporation from the skin, and consequent lessening of bodily heat, is partly or totally arrested.*

The most exhausting effects of heat are felt when the heat is continuous, *i.e.*, very great, day and night, and especially on sandy plains where the air is highly rarefied day and night. There is then really a lessened quantity of oxygen in a given cubic space.† Add to this fact that the respirations are lessened, and we have two factors at work which must diminish the ingress of oxygen, and thereby lessen one of the great agents of metamorphosis.

On the whole, even when sufficient perspiration keeps the body temperature within the limits of health, the effect of great heat in shade seems to be, as far as we can judge, a depressing influence lessening the nervous activity, the great functions of digestion, respiration, sanguification, and directly or indirectly the formation and destruction of tissues. Whether this is the heat alone, or heat and lessened oxygen, and great humidity, is not certain.

So bad have been the general and personal hygienic conditions of Europeans in India, that it is impossible to say what amount of the great mortality in that country is due to excess of heat over the temperature of Europe. Nor is it possible to determine the influence of heat alone on the endemic diseases of Europeans in the tropics—liver disease and dysentery. There is, perhaps, after all, little immediate connection between heat and liver disease.

Rapid Changes of Temperature.—The exact physiological effects have not yet been traced out; and these sudden vicissitudes are often met by altered clothing, or other means of varying the temperature of the body. The greatest influence of great changes of temperature, appears to be when the state of the body in some way coincides with or favours their action. Thus, the sudden checking of the profuse perspiration by a cold wind produces catarrhs, inflammations, and neuralgia. I have been astonished, however, to find how well even phthisical persons will bear great changes of temperature, if they are not exposed to moving currents of air; and there can be little doubt that the wonderful balance of the system is soon readjusted.

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* See Dr Kenneth Mackinnon's Treatise on Public Health, p. 27, on the effect of plenty of exercise even in the hot, and moist, and presumed unhealthy climate of Tirhoot, in Bengal. He proves that men can be much in the open air, even in the hot parts of the day, with impunity, and that when "they take exercise they are in the highest state of health." Still Dr Mackinnon believes the climate is exhausting.

† A cubic foot of dry air at 32° weighs 566·850 grains, and if the proportion of nitrogen and oxygen be assumed to be by weight 67 and 23 per cent., and the slight amount of carbonic acid be neglected, there will be in a cubic foot—

436·475 grains of nitrogen.
130·375 ,, oxygen.
566·850

As a man draws, on an average, when tranquil, 16·6 cubic feet per hour into his lungs, he will thus receive 130·375 × 16·6 = 2164·2 grains of oxygen per hour.

At a temperature of 80° the foot of air weighs 516·38 grains, and is made up by weight of—

397·61 grains of nitrogen.
118·77 ,, oxygen.
516·38

Therefore, in an hour if a man withdraws 16·6 cubic feet, he will receive 118·77 × 16·6 = 1971·6 grains of oxygen per hour. Or, in other words, in an hour he would receive 192·6 grains of oxygen less with the higher temperature, an amount equal to about 9 per cent. of the amount supplied at the lower temperature.

If saturated with moisture, a cubic foot of air will contain 130 grains of oxygen at 32°, and 112 grains at 100°.

SECTION II.

HUMIDITY.

According to their degree of humidity climates are divided into moist and dry. Professor Tyndall's observations have shown how greatly the humidity of the air influences climate, by hindering the passage of heat from the earth. As far as the body is concerned, the chief effect of moist air is exerted on the evaporation from the skin and lungs, and therefore the degree of dryness or moisture of an atmosphere should be expressed in terms of the relative (and not of the absolute) humidity, and should always be taken in connection with the temperature, movement, and density of the air, if this latter varies much from that of sea-level. The evaporating power of an atmosphere which contains 75 per cent. of saturation is very different, according as the temperature of the air is 40° or 80°. As the temperature rises, the evaporative power increases faster than the rise in the thermometer.

There is a general opinion that an atmosphere which permits free, without excessive, evaporation is the best; but there are few precise experiments.

The most agreeable amount of humidity to most healthy people is when the relative humidity is between 70 to 80 per cent. In chronic lung diseases, however, a very moist air is generally most agreeable, and allays cough. The evaporation from the lungs produced by a dry atmosphere appears to irritate them.

The moist hot siroccos, which are almost saturated with water, are felt as oppressive by man and beast; and this can hardly be from any other cause than the check to evaporation, and the consequent rise in the temperature of the body.

It is not yet known what rate of evaporation is the most healthy. Excessive evaporation, such as may be produced by a dry sirocco, is well borne by some persons, but not by all. Probably, in some cases, the physiological factor of perspiration comes into play, and the nerves and vessels of the skin are altered; and in this way perspiration is checked. We can hardly account, in any other way, for the fact, that in some persons, the dry sirocco, or dry hot land wind, produces harshness and dryness of the skin, and general malaise, which possibly (though there is yet no thermometric proof) may be caused by a rise of temperature of the body.

From the experiments of Lehmann on pigeons and rabbits, it appears that more carbonic acid is exhaled from the lungs in a very moist than in a dry atmosphere. The pathological effects of humidity are intimately connected with the temperature. Warmth and great humidity are borne, on the whole, more easily than cold and great humidity. Yet, in both cases, so wonderful is the power of adaptation of the body, that often no harm results.

The spread of certain diseases is supposed to be intimately related to humidity of the air. Malarious diseases, it is said, never attain their fullest epidemic spread unless the humidity approaches saturation. Plague and smallpox are both checked by a very dry atmosphere. The cessation of bubo plague in Upper Egypt, after St John's Day, has been considered to be more owing to dryness than to the heat of the air.

In the dry Harmattan wind, on the west coast of Africa, smallpox cannot be inoculated; and it is well known with what difficulty cowpox is kept up in very dry seasons in India. Yellow fever, on the other hand, seems independent of moisture, or will at any rate prevail in a dry air. The observations at Lisbon, which Lyons has recorded, show no relation to the dew-point.

With regard to other diseases, and especially to diseases of sanguification and nutrition, observations are much needed.

SECTION III.

MOVEMENT OF AIR.

This is a very important climatic condition. The effect on the body is twofold. A cold wind abstracts heat, and in proportion to its velocity; a hot wind carries away little heat by direct abstraction, but, if dry, increases evaporation, and in that way may in part counteract its own heating power. Both, probably, act on the structure of the nerves of the skin, and on the contractility of the cutaneous vessels, and may thus influence the rate of evaporation, and possibly affect also other organs.

The amount of the cooling effect of moving bodies of air is not easy to determine, as it depends on three factors, viz., the velocity of movement, the temperature, and the humidity of the air. The effect of movement is very great. In a still atmosphere an extremely low temperature is borne without difficulty. In the arctic expeditions still air many degrees below zero of Fahr. caused no discomfort. But any movement of such cold air at once chills the frame. It has been asserted that some of the hot and very dry desert winds will, in spite of their warmth, chill the body; and if so, it can scarcely be from any other reason than the enormous evaporation they cause from the skin. It is very desirable, however, that this observation should be repeated, with careful thermometrical observations on the body and surface.

SECTION IV.

WEIGHT OF THE AIR.

I shall not here enter into the question, whether the slight changes in the pressure of the atmosphere, which occur at any one spot, have any effect on health, or any influence on disease.

Effects of Considerable Lessening of Pressure.

When the difference of pressure between two places is considerable, a marked effect is produced, and there seems no doubt that the influence of mountain localities is destined to be of great importance in therapeutics. It is of particular interest to the army surgeon, as so many regiments in the tropics are, or will be, quartered at considerable elevations.

In ascending mountains there is rarefaction, *i.e.*, lessened pressure of air; on an average (if the weight of the air at sea-level is 14 ℔ on every square inch) an ascent of 900 feet takes off $\frac{1}{2}$ ℔; but this varies with height (see Measurement of Heights); there are also lowered temperature, and lessened moisture above 4000 feet; greater movement of the air; increased amount of light; greater sun radiation, if clouds are absent. The air is freer from germs of infusoria. Owing to the rarefaction of the air and lessened watery vapour there is greater diathermancy of the air; the soil is rapidly heated, but radiates also fast, as the heat is not so much held back by vapour in the air, hence there is very great cooling of the ground and the air close to it at night.

The physiological effects of lessened pressure begin to be perceptible at 2800 or 3000 feet of altitude (= descent of $2\frac{1}{2}$ to 3 inches of mercury); they are quickened pulse* (fifteen to twenty beats per minute); quickened respira-

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* *Balloon ascents.*—Biot and Gay Lussac at 9,000 feet = increase of 18 to 30 beats of the pulse.
Glaisher, . . at 17,000 ,, = ,, 10 to 24 ,,
,, . . at 24,000 ,, = ,, 24 to 31 ,,
The beats seem to augment in number with the elevation. These are safer numbers than those

tion (increase = ten to fifteen respirations per minute), increased evaporation from skin and lungs; lessened urinary water.* At great heights there is increased pressure of the gases in the body against the containing parts; swelling of superficial vessels, and occasionally bleeding from the nose or lungs. A sensation of weight is felt in the limbs from the lessened pressure on the joints. At altitudes under 6000 or 7000 feet the effect of mountain air (which is, perhaps, not owing solely to lessened pressure, but also, possibly, to increased light and pleasurable excitement of the senses) is to cause a very marked improvement in digestion, sanguification, and in nervous and muscular vigour.† It is inferred that tissue change is accelerated, but nothing definite is known.

The rapid evaporation at elevated positions is certainly a most important element of mountain hygiene. At Puebla and at Mexico the hygrometer of Saussure will often mark 37°, which is equal to only 45 per cent. of saturation (Jourdanet, "Du Mexique," p. 49), and yet the lower rooms of the houses are very humid, so that, in the town of Mexico, there are really two climates,—one very moist, in the rez-de-chaussée of the houses; one very dry, in the upper rooms and the outside air.

The diminution of oxygen, in a certain cubic space, is precisely as the pressure, and can be calculated for any height, if the barometer is noted. Taking dry air only, a cubic foot of air at 30 inches, and at 32° Fahr., contains 130·4 grains of oxygen. An ascent (about 5000 feet) which reduces the barometer to 25 inches will lessen this $\frac{1}{6}$th, or $\left(\frac{25 \times 130{\cdot}4}{30} = \right)$ 108·6 grains. But it is supposed that the increased number of respirations compensate, or more so, for this; and, in addition, it must be remembered that in experiments on animals, as long as the percentage of oxygen did not sink below a certain point (14 per cent.), as much was absorbed into the blood as when the oxygen was in normal proportion. Jourdanet has indeed asserted ("Du Mexique," p. 76) that the usual notion that the respirations are augmented in number in the inhabitants of high lands is "completely erroneous;" that the respirations are in fact lessened, and that from time to time a deeper respiration is voluntarily made as a partial compensation. But Coindet, from 1500 observations on French and Mexicans, does not confirm this; the mean number of respirations was 19·36 per minute for the French, and 20·297 for the Mexicans.‡

obtained in mountain ascents, as there is no physical exertion. In mountain climbing the increase is much greater.

* Vivenot, Virchow's Archiv, 1860, band xix. p. 492. This is probable, but not yet proved.

† Hermann Weber, "Climate of the Swiss Alps," 1864, p. 17.

‡ The statements of M. Jourdanet ("Du Mexique au point de Vue de son influence sur la vie de l'Homme," Paris, 1861,) are so adverse to general opinion, that it is to be hoped the subject will be soon thoroughly investigated. Jourdanet asserts that elevation "lessens the respiratory endosmosis;" that cattle imported into the mountains of Mexico suffer; horses, for example, breathe with difficulty, run badly, are often ill, have rheumatism, and often die of pleurisy. "As to man, the modifications he suffers, at first less visible, become with time still more evident, and while strangers acclimatise easily at sea-level in countries which are not malarious, and reach, in good health, an advanced age, those who live on the altitudes are more feeble and sickly, and seldom reach the natural term of human existence" (p. 79). This is attributed both to lessened pressure and lessened watery vapour, and a kind of anæmia is said to be very common in the city of Mexico and at Puebla. As this assertion is quite contrary to the experience of the Swiss Alpine regions, it has been examined by Coindet in Mexico, and is declared to be incorrect. Jourdanet states that the circulation is always increased, and in the disproportion between the circulation and the respiration he traces the origin of those "dangerous engorgements," which he believes to be the consequence of residence on the heights of Mexico (6000 to 7000 feet). A thorough examination of all these points could be made more thoroughly by the army surgeons on the Indian hill stations than by any body of men in the world, and it is to be hoped the inquiry will soon be systematically entered upon. At present Jourdanet's statements are, on the whole, much doubted.

Jourdanet (*loc. cit.* p. 291) asserts that the "respiratory aliments" are badly digested; that butter remains in the stomach; that starch and sugar render the mouth and tongue coated and destroy appetite; that alcohol remains a long time in the circulation. Whether there is any truth in this remains to be seen. It accords with M. Jourdanet's improbable hypothesis of the condition of respiration; and this perhaps renders the statement doubtful.

As a curative agent, mountain air (that is, the consequences of lessened pressure chiefly) ranks very high in all anæmic affections from whatever cause (malaria, hæmorrhage, digestive feebleness, even lead and mercury poisoning); and it would appear, from Hermann Weber's observations, that the existence of valvular heart disease is, if proper rules are observed, no contra-indication against the lower elevations (2000 to 3000 feet). Neuralgia, gout, and rheumatism are all benefited by high Alpine positions (H. Weber). Scrofula and consumption have been long known to be rare among the dwellers on high lands, and the curative effect on these diseases of such places is also marked; but it is possible that the open air life which is led has an influence, as it is now known that great elevation is not necessary for the cure of phthisis.*

Dr Hermann Weber, in his important work on the Swiss Alps, thus sums up the present evidence:—

"Tubercular phthisis occurs not rarely in the lower mountainous or sub-Alpine region, but in the true Alpine region it seems to be almost absent. Thus it is of very rare occurrence among the priests on the Great St Bernard; and Dr Brügger has scarcely ever observed it amongst those inhabitants of the Upper Engadin who have not resided in other countries; and has further found that this disease is generally cured, in natives of the Engadin, when they return to their mountains, before it has made great progress. Dr Albert of Briançon, in the Dauphiné (4283 feet above the sea-level), bears, according to Lombard (*loc. cit.* p. 93), the same testimony. These observations are quite in harmony with what we know of the occurrence of tubercular phthisis in other mountainous countries. Thus patients affected with phthisis at Lima are sent on the adjacent mountains of Peru, where phthisis is scarcely known at an elevation of about 8000 feet. It is described as very rare at Mexico (7000 feet) and Quito (8700 feet), and still more so in higher elevations. The elevation beyond which phthisis becomes rare, or is absent, seems to vary considerably in different latitudes, and to become lower as we proceed towards the poles. In the tropical zone it may be regarded as becoming rare above 7000 feet; in the warmer temperate zone, above 3500 to 5000 feet; in the colder temperate zone, above 1300 to 3000 feet elevation. In Switzerland, between 46° and 48° N. lat., the frequency of its occurrence diminishes above 3000 feet; in the Black Forest, between 47° and 49° N. lat., above 2500; in the mountains of Thüringen and Silesia, and in the Harz, between 50° and 52° N. lat., above 1200 to 1400 feet. Fuchs ('Medicinishe Geographie,' 1853, p. 35), states that at Brotterode (1840 feet), in the mountains of Thüringen, the percentage of deaths from phthisis is only 0·9. Brehmer assures us that in the neighbourhood of Görbersdorf, in Silesia (1700 feet), tubercular phthisis has never been seen by him amongst the inhabitants—('Die Chronische Lungen-schwindsucht,' Berlin, 1857, p. 134)—an obser-

* Some time ago a remarkable paper was published by Dr James Blake of California on the treatment of phthisis ("Pacific Medical Journal," 1860). He adopted the plan of making his patients live in the open air; in the summer months he made them sleep out without any tent; the result was an astonishing improvement in digestion and sanguification; the resistance to any ill effects from cold and wet is described as marvellous. As Dr Blake is well known to be perfectly trustworthy, these statements are worthy of all consideration.

vation which Dr H. Beigel, who has for several years resided at Reinerz (1700 feet above the level of the sea, and very near to Görbersdorf), has, in a personal communication to me, to a great degree confirmed." (Weber, *op. cit.* p. 22.)

Although on the Alps phthisis is thus arrested in strangers, in many places the Swiss women on the lower heights suffer greatly from it; the cause is a social one; the women employed in making embroidery congregate all day in small, ill-ventilated, low rooms, where they are often obliged to be in a constrained position; their food is poor in quality. Scrofula is very common. The men who live an open air life are exempt; therefore, in the very place where strangers are getting well of phthisis the natives die from it—another instance that we must look to local conditions and social habits for the great cause of phthisis. It would even seem probable that, after all, it is not indeed elevation and rarefaction of air, but simply plenty of fresh air and exercise, which cures phthisis.

Jourdanet, who differs from so much that is commonly accepted on this point, gives additional evidence on this point. At Vera Cruz phthisis is common; at Puebla and on the Mexican heights, it is almost absent (à peu près nulle). The fact seems certain, whatever may be the fate of Jourdanet's explanation of it.

The diseases for which mountain air is least useful are—rheumatism, at the lower elevations where the air is moist; above this rheumatism is improved; and chronic inflammatory affections of the respiratory organs (?) The "mountain asthma" appears, however, from Weber's observations, to be no specific disease, but to be common pulmonary emphysema following chronic bronchitis.

It seems likely that pneumonia, pleurisy, and acute bronchitis, are more common in higher Alpine regions than lower down.

Effects of increased Pressure.—The effects of increased pressure have been noticed in persons working in diving-bells, &c., or in those submitted to treatment by compressed air. (At Lyons and at Reichenhall* especially.) When the pressure is increased to from $1\frac{1}{4}$ to 2 atmospheres, the pulse becomes slower, though this varies in individual cases; the mean lessening is 10 beats per minute; the respirations are slightly lessened (1 per minute); evaporation from the skin and lungs is said to be lessened (?); there is some recession of blood from the peripheral parts; there is a little ringing and sometimes pain in the ears; hearing is more acute; the urine is increased in quantity; appetite is increased; it is said men will work more vigorously. When the pressure is much greater (two or three atmospheres) the effects are sometimes very marked; great lowering of the pulse, heaviness, headache, and sometimes, it is said, deafness. It is said † that more oxygen is absorbed, and that the venous blood is as red as the arterial; the skin also sometimes acts more, and there may even be sweating. The main effect is to lessen the quantity of blood in the veins and auricles, and to increase it in the arteries and ventricles; the filling of the ventricle during the relaxation takes place more slowly. The diastolic interval is lengthened, and the pulse is therefore slower.

When the workmen leave the compressed air they are said to suffer from hæmorrhages and occasional nervous affections, which may be from cerebral or spinal hæmorrhage.‡

As a curative agent in phthisis, the evidence is unfavourable.

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* For an account of the effects noted at Reichenhall, see Dr Burdon-Sanderson's account in The Practitioner, No. iv., 1868, p. 221.

† Foley. Du Travail dans l'air comprimé, Gaz. Hebdom, 1863, No. 32.

‡ See Limousin in Canstatt, 1863, band ii. p. 105, and Babington in "Dublin Quarterly Journal," Nov. 1864.

SECTION V.

COMPOSITION OF THE AIR.

The proportionate amounts of oxygen and nitrogen remain very constant in all countries, and the range of variation is not great.

So also, apart from the habitations of men, the amount of carbonic acid is (at elevations occupied by men) constant. The variations in watery vapour have been already noticed.

The only alterations in the composition of the air which come under the head of climate, are changes in the state in which oxygen exists (for no change is known to occur in nitrogen), and the presence of impurities.

SUB-SECTION I.—OZONE.

Since the discovery of ozone by Schönbein, it has seemed not unlikely that variations in the amount of this substance would be one reason of climatic differences. At present, however, it cannot be said we have any safe data to go upon; this has arisen chiefly from the imperfection of the test for ozone (see METEOROLOGY). A molecule of ozone has been surmised to be made up of three atoms of oxygen. Admitting the presence of ozone in the air, from the recent experiments of Schönbein and Andrews, the paper tests are uncertain, and are also acted on by other substances.* This much, however, is certain, that the reaction given by Schönbein's or Moffat's papers is different in different places, and differs in the same place on different days, even when wind, light, &c., are equal. So that there is a measurable change in the air, which it is certainly worth while to take notice of.

The reaction with these papers is greater in pure than in impure air; at the sea-side than in the interior; with south and west winds (in this country and in India?) than with north and east. It is greater in mountain air than on plains.

The reaction is often absent from hospital wards, though present in the air around them.

According to Moffat, the indications are greater when the barometer, the mean daily temperature, and the dew-point are all high. Lowe's observations show that indications are less either when the air is dry or quite saturated; he also found more reaction when the barometer is low. The reaction is said to be at its minimum in the autumn in this country.

As already stated, the great imperfections in the reagent (see METEOROLOGY) make it desirable to avoid all conclusions at present, but one or two points must be adverted to.

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* The researches of Meissner (Unters. über den Sauerstoff, 1863) show that when oxygen is converted into ozone by electricity (in which process it lessens in volume and becomes heavier—*Andrews*), and is then led through iodide of potassium, every trace of ozone is removed; but when the gas which emerges from the solution of iodide of potassium is passed through pure water, a thick white mist appears, sometimes so thick as to render the surface of the water quite opaque. A certain amount of vapour is necessary for its formation. Meissner at first called this smoke or mist-forming gas atmizone (ατμίζω, I smoke), but subsequently ascertained that it was identical with Schönbein's antozone. The mist can be poured like carbonic acid from one vessel to another; on standing, it gradually becomes transparent, and drops of water are deposited; when it has once disappeared it cannot be reproduced, and the air has all the properties of ordinary oxygen. Thus atmizone has the property of attracting moisture, and giving it the character of a cloud. Von Babo states that these fumes are only produced in the presence of nitrogen or oxidisable substances, and consist of peroxide of hydrogen. But the whole matter is extremely obscure.

1. Owing probably to the oxidising power of ozone when prepared in the laboratory, a great power of destruction of organic matter floating in the air has been ascribed to ozone by Schönbein, and the absence of ozone in the air has been attributed by others to the amount of organic matter in the air of towns. Even the cessation of epidemics (of cholera, malarious fevers) has been ascribed to currents of air bringing ozone with them. The accumulation of malaria at night has been ascribed to the non-production of ozone by the sun's rays (Uhlo). The effect of stagnant air in increasing epidemics has also been ascribed to the absence of ozone.

It seems clear that the substance giving the reaction of ozone is neither deficient in marshy districts, nor when ozone is conducted through marsh dew does it destroy the organic matter.* Is there any experimental proof that it acts on the organic impurities of respiration? I have been able to find none recorded, except the fact already noticed, that the reaction is least in impure air. It is incumbent on the supporters of this view (which may or may not be correct) to bring forward more experimental proof. I do not see any evidence of weight to prove that deficiency in ozone has assisted the spread of epidemics of any of the specific diseases, or that excess has checked them.

2. On account of the irritating effect of ozone, when rising from an electrode, Schönbein believed it had the power of causing catarrh, and inferred that epidemics of influenza might be produced by it. He attempted to adduce evidence, but at present it may safely be said that there is no proof of such an origin of epidemic catarrhs.

3. A popular opinion is, that a climate in which there is much ozone (*i.e.* of the substance giving the reaction with iodide and starch paper) is a healthy, and, to use a common phrase, an exciting one. The coincidence of excess of this reaction with pure air lends some support to this, but, like the former opinions, it still wants a sufficient experimental basis.

On the whole, the subject of the presence and effects of atmospheric ozone, curious and interesting as it is, is very uncertain at present; experiments must be numerous, and inferences drawn from them will for a long time have to be received with caution.

SUB-SECTION II.—MALARIA.

The most important organic impurity of the atmosphere is malaria (for Air of Marshes, see page 94), and when a climate is called "unhealthy," in many cases it is simply meant that it is malarious. In the chapters on SOILS and AIR the most important hygienic facts connected with malaria have been noted. In this place it only remains to note one or two of the climatic points associated with malaria.

1. *Vertical Ascent.*—A marsh or malarious tract of country existing at any point, what altitude gives immunity from the malaria, supposing there is no drifting up ravines? It is well known that even a slight elevation lessens danger—a few feet even, in many cases, but complete security is only obtained at greater heights. Low elevations of 200 to 300 feet are often, indeed, more malarious than lower lands, as if the malaria chiefly floated up.

At present the elevation of perfect security in different parts of the world is not certainly determined, but appears to be—

* In addition to what has been previously said (p. 95), Grellois has lately stated that he found more ozone over a marsh than elsewhere. An interesting series of observations on ozone in the Bombay Presidency has been made by Dr Cook, and, if continued, will probably give us some reliable data in a few years.

Italy,	400 to 500 feet.*	
America (Appalachia),	3000 ,,	
California,†	1000 ,,	
India,	2000 ,, 2000 ,,	
West Indies,	1400 ,, 1800 up to 2200 feet.	

But these numbers are so far uncertain that it has not always been seen that the question is not, whether marshes can exist at these elevations (we know they can be active at 6000 feet), but whether the emanations from a marsh will ascend that height without drifting up ravines? I cannot help suspecting that 1000 to 1200 feet would generally give security.

2. *Horizontal Spread.*—In a calm air Levy‡ has supposed that the malaria will spread until it occupies a cube of 1400 to 2000 feet, which is equivalent to saying it will spread 700 to 1000 feet horizontally from the central point of the marsh. But currents of air take it great distances, though the best observations show that these distances are less than were supposed, and seldom overpass one or two miles, unless the air-currents are rapid and strong. The precise limits are unknown, but it is very doubtful if the belief in transference of malaria by air-currents for 10, 20, or even 100 miles, is correct.

3. *Spread over Water.*—The few precise observations show that this differs in different countries. In the Channel, between Beveland and Walcheren, 3000 feet of water stopped it (Blane). In China and the West Indies a further distance is necessary. In China three-quarters of a mile has been effectual;§ in the West Indies one mile. Grant thinks salt water more efficacious than fresh.

SECTION VI.

ELECTRICAL CONDITION—LIGHT.

That these, as well as heat, are important parts of that complex agency we call Climate, seems clear; but little can be said on the point. In hot countries positive electricity is more abundant; but the effect of its amount and variation on health and on the spread and intensity of diseases is quite unknown. All that has been ascribed to it is pure speculation. The only certain fact seems to me that the spread of cholera is not influenced either by its presence or absence.

With regard to light, the physiological doctrine of the necessity of light for growth and perfect nutrition makes us feel sure that this is an important part of climate, but no positive facts are known.

Dr Roscoe has proposed a plan of measuring the intensity of light, which will probably be very useful in Meteorology.

A sensitive photographic paper is prepared, and the time given to produce a constant tint is noted. At present, however, the apparatus is not sufficiently perfected to be commonly used.

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* Carrière, quoted by Levy, t. i. p. 491.
† This information was given me by my friend Dr James Blake.
‡ T. i. p. 464.
§ Grant (quoted by Chevers), "Indian Annals," 1859, p. 636.

CHAPTER XVIII.

ON THE PREVENTION OF SOME OF THE IMPORTANT AND COMMON DISEASES IN THE ARMY.

THERE are two modes by which we may attempt to prevent the occurrence of disease.

1. By conforming with the general rules of hygiene, by which the body and mind are brought into a state of more vigorous health.

2. By investigating and removing the causes of the diseases which we find actually in operation. This part of the inquiry is in fact a necessary supplement to the other, though in proportion to the observance of the general rules of hygiene, the causes of disease will gradually be removed. At present, however, we have to deal with the facts before us,—viz., that there are a great number of diseases actually existent which must form the subject of investigation. We proceed in this case from the particular to the general, whereas, in the first mode, we deduce general rules which have to be applied to individual instances.

Hygiene is in this direction an application of etiology, and etiology is the philosophy of medicine; while in its turn the very foundation and basis of etiology is an accurate diagnosis of disease. Unless diseases are completely identified, all inquiry into causes is hopeless. Let us remember, for example, what utter confusion prevailed in our opinions as to causes and preventive measures at the time when typhus and typhoid fevers were considered identical, or when paroxysmal fever and the true yellow fever or vomito were thought to own a common cause. Any useful rules of prevention were simply impossible —as impossible as at present in many of the diseases of nutrition, which, in the proper sense of the word, are yet undiagnosed.

The advance of diagnosis has of late years been owing not merely to improved methods of observation, but to the more complete recognition of the great principle of the invariableness of causation. The sequence of phenomena in the diseased body proceeds with the same regularity and constancy as in astronomy or chemistry. Like causes always produce like effects. To suppose that from the same cause should proceed a sequence of phenomena so utterly distinct as those of typhus and typhoid fever, now seems incredible; yet with a full, or at any rate a sufficient, knowledge of the phenomena, it was at one time almost universally believed that these two perfectly distinct diseases owned a common origin. At the present moment, the superficial resemblance between gout and rheumatism causes them to be put together in almost all systems of nosology, although, with the exception of the joints being affected, the diseases have almost nothing in common.*

* Few things have done more harm in the study of etiology than the tendency, by hasty classification, to confound perfectly distinct things. At present classification must be looked upon merely as a convenient arrangement, not as expressing any real generalisation. The employment of such terms as miasmatic, zymotic, &c., is not only justifiable, but useful as a convenient mode of classification; but if such terms are allowed to carry more weight than should attach to them, and make us overlook the absolutely different and uninterchangeable character

In proportion as this great principle is still more constantly applied, and as our means of diagnosis advance, and consequently, causes are more satisfactorily investigated, methods of prevention will become obvious and precise. At present they are very far from being so. In many cases they are founded on very imperfect observation; and very frequently all that can be done is to apply general sanitary rules, without attempting to determine what are the special preventive measures which each disease requires.

It is not necessary, however, that we should wait until the causation of any disease is perfectly understood. We must act, as in so many other affairs, on probability; and endeavour to remove those conditions which, in the present state of our knowledge, seem to be the most likely causes of the disease. It may be that, in some cases, we may be attacking only subsidiary or minor causes, and may overlook others equally, or more, important. In some cases, indeed, we may overlook entirely the effective causes, and may be fighting with shadows. Still, even from mistakes, progress often arises—indeed, the difficult path of human knowledge is perhaps always through error.

The term cause is applied by logicians to any antecedent which has a share in producing a certain sequence; and it is well known that in many diseases two sets of causes are in operation—one external, and one internal to the body (exciting, and predisposing). The investigation of the internal causes, which in some cases are necessary to the action of the external causes, is equally curious and intricate as that of the external causes, and in some respects is even more obscure; but measures of prevention must deal with them, as well as with the external causes.

In this chapter I can, of course, only venture to enumerate very briefly, and without discussion, what seem to be the best rules of prevention for the principal diseases of soldiers. To enter on the great subject of the prevention of disease generally, and to discuss all the complicated questions connected with causation, would demand a volume.

I have endeavoured to preserve the simple and practical character which I have attempted to give to the other parts of this manual.

SECTION I.

THE SPECIFIC DISEASES.*

Paroxysmal Fevers.

External Cause.—This is presumed to be putrescent, or at any rate, decomposing vegetable matter (see pages 70, 94, and 294), derived from a moist and putrescent soil, which is carried into the body by the medium of water or of air.†

If by water, a fresh source must be obtained. Well water is generally safe, but not always. Rain water may be unsafe, if the tanks are not clean. If a fresh source cannot be obtained, boiling, charcoal, and alum appear to be the best preventive measures.

If the introduction be by air, and if the locality cannot be left, the most approved plan is elevation to at least 500 feet above *the source of the poison*

of the causes of the several diseases thus classed together for convenience, they can only be productive of harm. In respect both of causes and of preventive measures, we must at present study each disease separately, and no disease is worth studying scientifically as to causes and prevention until its diagnosis is quite certain.

* In enumerating these diseases, I have followed simply a convenient order, and have only referred to the most common diseases of soldiers.

† I have not thought it desirable to allude here to the views of Salisbury that a species of palmella causes intermittents, or to other similar views; they require more investigation before we can practically act on them.

in temperate climates; and 1000 to 1500 feet in the tropics, or higher still, if possible.* If this plan cannot be adopted, two points must be aimed at—viz., to obviate local, and to avoid drifting malaria. Thorough subsoil draining; filling up moist ground when practicable; paving, or covering the ground with herbage kept closely cut, are the best plans for the first point. For the second, belts of trees, even walls, can be interposed; or houses can be so built, as not to present openings towards the side of the malarious currents.

The houses themselves should be raised above the ground on arches; or, if wooden, on piles. Upper floors only should be occupied. The early morning air, for three hours after sunrise, should be avoided; and next to this, night air.

Internal Causes.—The conformation, or structural condition, which permits the external cause to act, is evidently not equal in different individuals, or in different races; but we are quite ignorant of its nature. It is not removed by attacks of the disease; but, on the contrary, after repeated attacks of ague, a peculiar condition (of the nerves?) is produced, in which the disease can be brought on by causes, such as cold, dietetic errors, which could never have caused it in the first instance. The internal predisposition is greatly heightened by poor feeding, anæmia, and probably by scurvy.

To remove the internal causes our only means at present are the administration of antiperiodics, especially quinine; and good and generous living, with iron medicines. The use of flannel next the skin, and of warm clothing generally; warm coffee, and a good meal before the time of exposure to the malaria, and perhaps moderate smoking (?) are the other chief measures. Wine in moderation is part of a generous diet; but spirits are useless, and probably hurtful.

Yellow Fever.

External Cause.—During the last few years the progress of inquiry has entirely disconnected true yellow fever from malaria, though yellowness of the skin is a symptom of some malarious fevers. Yellow fever is a disease of cities and of parts of cities, being often singularly localised, like cholera. In the West Indies it has repeatedly attacked a barrack (at Bermuda, Trinidad, Barbaboes, Jamaica), while no other place in the whole island was affected. In the same way (at Lisbon, Cadiz, and many other places) it has attacked only one section of a town, and, occasionally, like cholera, only one side of a street. In the West Indies it has repeatedly commenced in the same part of a barrack. In all these points, and in its frequent occurrence in non-malarious places, in the exemption of highly malarious places, in its want of relation to moisture in the atmosphere, and its as evident connection with putrefying fæcal and other animal matters, its cause differs entirely from malaria.

If these points were not sufficient, the fact that the agent or poison which causes yellow fever is portable, can be carried and introduced among a community,† and is increased in the bodies of these whom it attacks, indicates

* It must be understood that these heights are assumed to be *above* a marsh. They will not secure from malaria from marshes, if situated at that or a much greater height. A marsh at Erzcroum is 6000 feet above sea-level; one at Puebla, in New Mexico, is 5000 feet; both cause fevers.

† Cases of the Bann, Eclair, Icarus, and several others. The late remarkable introduction of yellow fever from Havannah into St Nazaire, in France (near Brest), is most striking, and cannot be explained away. It spread both from the ship, and, in one instance, from persons. (See "Aitken's Medicine," 5th edit. 1868; and "Report on Hygiene for 1862," in the Army Medical Report, by the author.) The introduction into Rio in 1849, and into Monte Video, are still more striking cases of importation; and lately a case very similar to that of St Nazaire has occurred at Swansea. (See Report by Dr Buchanan to the Medical Officer of the Privy Council, 1866.)

that the two agencies of yellow fever and paroxysmal fevers are entirely distinct.*

That great point being considered settled, the inquiry into the conditions of spread of the yellow fever becomes easier. The points to seize are its frequent and regular localisation and its transportation. The localisation at once disconnects it with any general atmospheric wave of poison; it is no doubt greatly influenced by temperature, and is worse when the temperature is above 70° Fahr. Though it will continue to spread in a colder air than was formerly supposed, it does not spread rapidly, and appears to die out, but even temperature does not cause it to become general in a place.

The localising causes are evidently (cases of Lisbon, Gibraltar, West Indies, &c.) connected with accumulation of excreta round dwellings, and overcrowding. Of the former there are abundant instances, and it is now coming out more and more clearly that, to use a convenient phrase, yellow fever, like cholera and typhoid fever, is a fæcal disease. And here we find the explanation of its localisation in the West Indian barracks in the olden time. Round every barrack there were cess-pits, often open to sun and air. Every evacuation of healthy and sick men was thrown into perhaps the same places. Grant that yellow fever was somehow or other introduced, and let us assume (what is highly probable) that the vomited and fæcal matters spread the disease, and it is evident why, in St James' Barracks at Trinidad, or St Ann's Barracks at Barbadoes, men were dying by dozens, while at a little distance there was no disease. The prevalence on board ship is as easily explained: Granted that yellow fever is once imported into the ship, then the conditions of spread are probably as favourable as in the most crowded city; planks and cots get impregnated with the discharges, which may even find their way into the hold and bilge. No one who knows how difficult it is to help such impregnation in the best hospitals on shore, and who remembers the imperfect arrangements on board ship for sickness, will doubt this. Then, in many ships, indeed in almost all in unequal degrees, ventilation is most imperfect, and the air is never cleansed.

Overcrowding, and what is equivalent, defective ventilation, is another great auxiliary; and Bone† relates several striking instances.‡

The question of the origin of yellow fever is one which cannot be considered in this volume, and at present no preventive rules of importance can be drawn from the discussion.

The chief preventive measures for the external cause are these:—

1. The portability being proved, the greatest care should be taken to prevent introduction, either by sick men, or by men who have left an infected ship. The case of the "Annie Marie" (see "Aitken's Medicine," and "Report on Hygiene" in the Army Medical Report for 1862) has made it quite uncertain what period of time should have elapsed before an infected ship can be considered safe; in fact, it probably cannot be safe until the cargo has

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* As more care is taken, the symptoms of the two diseases also are found to be diagnostic, and if it were not for the constant use of the unhappy term "remittent," the confusion would not have so long prevailed.

An interesting instance of good diagnosis was made by the French at Vera Cruz in 1861. In the spring the vomito prevailed, and then disappeared. Some months afterwards, cases of a disease occurred so like yellow fever that they were at first taken to be that disease, but on a closer examination they were found to be clearly paroxysmal, and to yield to quinine.—*Rec. de Mem. de Méd. Milit.* 1863.

† Yellow Fever, by G. F. Bone, Assist.-Surg. to the Forces. (The materials of this work are partly derived from the MSS. of the author's father, Inspector-General Bone.)

‡ For example, in the same barrack, the windward rooms have been quite healthy, and the leeward rooms attacked. Men in the latter have ceased to have cases of the disease when moved to the former locality. (See a good case in Bone, *op. cit.* p. 13.)

been discharged and the ship thoroughly cleansed. Still, it appears, that if men leaving an infected place or ship pass into places well ventilated and in fair sanitary condition, they seldom carry the disease; in other words, the disease is seldom portable by men, but it will occur. It appears necessary, also, to consider that the incubative period is longer than usually supposed, probably often fourteen or sixteen days. In the case of a ship it seems desirable not to consider danger over until at least twenty days have elapsed since the cure or death of the last case, and even at that time to thoroughly fumigate the ship with chlorine and nitrous acid before the cargo is touched. Men working on board such a ship should work by relays, so as not to be more than an hour at a time in the hold.

In case men sick with yellow fever must be received into a barrack or hospital, they should be isolated, placed in the best ventilated rooms at the top of the house, if possible, or, better still, in separate houses, and all discharges mixed with zinc sulphate and zinc chloride, and separately disposed of, and not allowed to pass into any closet or latrine.

2. The introduction by drinking-waters not being disproved, care should be taken that the possibility of this mode of introduction be not overlooked.

3. Perfect sewerage and ventilation of any station would probably in great measure preserve from yellow fever, but in addition, in the yellow fever zone, elevation is said to have a very great effect, though the confusion between malarious fevers and the vomito renders the evidence on this point less certain, and the late introduction into Newcastle in Jamaica (4200 feet), and the frequent occurrence at Xalapa (4330 feet), as well as its prevalence on high points of the Andes (9000 feet) (A. Smith), show that the effect of mere elevation has been overrated. Still, as a matter of precaution, all stations in yellow-fever districts should be on elevations above 2000, and if possible 3000 feet.

4. If an outbreak of yellow fever occurs in a barrack, it is impossible then to attempt any cleansing of sewers; the only plan is to evacuate the barracks. This has been done many times in the West Indies with the best effects. As a preventive measure, also, evacuation of the barracks, and encampment at some little distance, is a most useful plan. Before the barrack is re-occupied, every possible means should be taken to cleanse it; sewers should be thoroughly flushed; walls scraped, lime-washed, and fumigated with nitrous acid. If a barrack cannot be altogether abandoned, the ground floors should be disused. There are several instances in which persons living in the lowest story have been attacked, while those above have escaped.

5. In all buildings where sick are, or where yellow fever prevails, there should be constant fumigation with nitrous acid, which seems to be, as far as we know, the best disinfectant for this disease.

6. If it appears on board ship, take the same precautions with regard to evacuations, bedding, &c. Treat all patients in the open air on deck, if the weather permit; run the ship for a colder latitude; land all the sick as soon as possible, and cleanse and fumigate the ship.

Internal Cause.—Recent arrival in a hot country has been usually assigned as a cause, but the confusion between true yellow fever and severe febricula (ardent fever or causus) and malarious fevers, renders it uncertain how far this cause operates.* Still, as a matter of precaution, the present plan of three or

* In the older time in Jamaica it was, however, always noticed that the worst attacks occurred in regiments during the first twenty-four, and especially the first twelve months. In thirteen epidemics in different regiments, four occurred in less than six months after landing, seven in less than twelve months, and two in less than twenty-four months. But it has been stated that residence in one place, though it may secure against the yellow fever of that, does not

four years' Mediterranean service before passing to the West Indies seems desirable. Different races possess the peculiar habit which allows the external cause to act in very different degrees; this is marked in the cases of negroes and mulattoes as compared with white men, but even in the European nations it has been supposed that the northern are more subject than the southern nations. Of the sexes, women are said to be less liable than men.

This predisposition is increased by fatigue,* and it is said, especially when combined with exposure to the sun; by drinking, and by improper food of any kind which lowers the tone of the body.†

No prophylactic medicine is known; quinine is quite useless.

Little, therefore, can be done to avert the internal causes, except care in not undergoing great fatigue, temperance, and proper food. The external conditions are the most important to attend to.

Cholera.

External Cause.—As in the case of yellow fever, we have no certain clue to the origin of cholera, and in some respects the propagation of the disease is very enigmatical. The way, for example, in which the disease has spread over vast regions, and has then entirely disappeared,‡ and the mode in which it seems to develop and decline in a locality, in a sort of regular order, are facts which we can only imperfectly explain.

But as far as preventive measures are concerned, the researches of the last few years seem to have given us indications on which we are bound to act, though they are based only on a partial knowledge of the laws of spread of this poison.§

These indications are—

1. The portability of the disease, *i.e.*, the carriage of cholera from one place to another by persons ill with the disease, both in the earliest stage (the so-called premonitory diarrhœa), and the later period, and in convalescence.‖ The carriage by healthy persons coming from infected districts is not so certain; but there is some evidence.¶ It is clear this last point is a most important one, on which it is desirable to have more complete evidence. The occasional carriage by soiled clothes, though not on the whole common, has also evidence in its favour.

Whatever may be the final opinion on all these points, we are bound to act as if they were perfectly ascertained. It is usually impossible to have rigid quarantines; for nothing short of absolute non-communication would be

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protect against the disease in another locality. It is much to be wished that all these assertions which abound in books should be tested by figures. That is the only way of coming to a decision.

* Arnold, "Bilious Remittent Fever," 1840, p. 32.

† Bone has given a *receipt* for making yellow fever. It is simply placing men in the West Indies under the old system, which seemed to include every imaginable sanitary error, and yellow fever would be, he affirmed, certainly produced.

‡ There is, of course, no doubt that the common autumnal cholera, however much it may resemble superficially the Indian cholera, is quite a separate disease.

§ I am unable to enter fully into the evidence for each position, but I think they will all be admitted without difficulty. I have also not entered into the question on the possible nature of the cause of cholera, whether fungoid or otherwise, as I think a practical work of this kind is not the place for it.

‖ With respect to convalescence, the only evidence I know of is given by Volz, quoted by Hirch, Jahresb. für ges. Med. 1868, band ii. p. 221.

¶ Especially in the Mauritius outbreaks, where parties of coolies coming from places where cholera prevailed, but being themselves healthy, gave cholera to other parties of coolies who had arrived from India, and had no disease among them. Dr Adams (Army Medical Report, vol. vi. p. 348), in his excellent Report on Cholera in Malta, states, "There are many pointed facts to show that cholera may be introduced and communicated to susceptible persons by healthy individuals from infected districts."

useful, and this is impossible except in exceptional cases. For persons very slightly ill, or who have the disease in them but are not yet apparently ill, or possibly who are not and will not be ill at all, can give the disease, and therefore a selection of dangerous persons cannot be made. Then as the incubative stage can certainly last for ten or twelve days, and there are some good cases on record where it has lasted for more than twenty, it is clear that quarantine, unless enforced for at least the last period of time, may be useless. The constant evasions also of the most strict cordon render such plans always useless. An island, or an inland village, far removed from commerce, and capable for a time of doing without it, may practise quarantine and preserve itself; but, in other circumstances, both theory and actual experiments show that quarantine fails.*

This difficulty, however, of carrying out efficient isolation is no argument against taking every precaution against communication, and keeping a strict watch and control over every possible channel of introduction. In this way, by isolation of the individual, or of bodies of men, as far as possible, and by looking out for and dealing with the earliest case, an outbreak may perhaps be checked, especially by discovering the diarrhœal attacks, and by using disinfectants both to the discharges and to linen.† In the case of troops coming from infected districts, they should be kept in separate buildings for twenty days, and ordered to use only the latrines attached to them, in which disinfectants should be freely used.

2. It is held by many that cholera can also arise spontaneously in Lower Bengal, or can spread (whatever have been its origin in a place) by means of winds. With the first supposition we cannot deal, as we know nothing of the conditions of spontaneous origin, if it really occurs; but as far as winds are concerned, without attempting to decide the point or to state the limits of the transmission, it is a matter of prudence to act as they did carry the poison. The Indian rule is to march at right angles to the wind, and never against it or with it if it can be avoided. The spreading by the winds in India has been usually ascribed to the custom of throwing all the cholera evacuations on the ground; there they get dried, and then are lifted by the wind and driven to other parts. This seems probable, but no decided proof has been given; and an argument against it may be raised on the difficulty of accounting for the immunity of adjacent places if such transmission were common.

3. The introduction of the disease into any place is considered by most observers to be connected with the choleraic discharges, either when newly passed, or, according to some, when decomposing. The reasons for this are briefly these: the portability being certain, the thing carried is more likely to be in the discharges from the stomach and bowels than from the skin or breath (the urine is out of the question), and for these reasons: water can communicate the disease, and this could only be by contamination with the discharges; water contaminated by discharges has actually given the disease;

* When circumstances are favourable (as respects trade and intercourse), however, good quarantine may be successful even on the mainland. This was shown in Algeria in 1867. See Dr Dukerley's "Notice sur les Mesures de Préservation prises à Batna (Algérie) pendant le Cholera de 1867," Paris, 1868, for a very interesting account of those successful measures, of which strict isolation and constant hygienic measures were the principal. So also in America Dr Woodward states (Circular on Cholera, No. 5, Surgeon-General's Office, Washington, 1867) that "the general tenor of army experience is strongly in favour of quarantine."

† The Indian Government are now cautiously attempting to limit the spread of cholera by superintending and controlling the pilgrimages, which are so common a cause of the spread of cholera in India. The Report of the Cholera Committee (Inspector-General Mackenzie, Colonel Silva, and Dr Ranking) to the Madras Government, published at Madras in 1868, gives a great deal of important evidence on this point, and in addition lays down excellent rules for the management of pilgrimages.

in some cases a singularly local origin is proved, and this is always a latrine, sewer, or receptacle of discharges, or a soil impregnated with choleraic evacuations; soiled linen has sometimes given it, and this is far more likely to be from discharges than from the perspiration; animals (white mice and rabbits) have had cholera produced in them from feeding on the dried discharges. Finally, in the history of the portability of cholera, there are many instances in which, while there has been decided introduction by a diseased person into a place, there has been no immediate relation between that person and the next case; in other words, the cause must be completely detachable from the first case, and must be able to act at a distance from his body; it is therefore far more probable that the discharges are this carrying agency, than that any effluvia should pass off from the lungs and skin which could spread to a great distance.

Enough has been said to show that the discharges must receive the most careful attention. Every discharge ought to be disinfected with strong substances liberally used; the best are carbolic acid (in large quantity), chloride of zinc, chloride of lime, or, if none of these are at hand, good quicklime (see Disinfectants, p. 367). Although the results of disinfection of the discharges have not hitherto been encouraging, the plan has seldom been completely tried. All latrines should be disinfected, sewers flushed, carbolic acid poured down them, and every means taken to keep them ventilated.

What should be done with the disinfected discharges? Should they be allowed to pass into sewers, or buried in the ground? They must in some way be got rid off. Sewers certainly afford an easy mode of disposing of them; and as the discharges are mixed with much water, and are rapidly swept away in them, and as the temperature of the sewers is low, and decomposition is delayed, it is quite possible that sewers may be a means of freeing a town from choleraic discharges more easily than any other plan. And it appears to be a fact, that in the well-sewered towns in England the cholera of 1865 and 1866 never attained any wide spread. In large towns, also, there are no other means of disposing of the discharges. But may not sewers be a means of dissemination,* and thus, as in some outbreaks of enteric fever, be a source of danger? And again, when sewerage is poured over land, as it will be soon throughout all England, are we quite sure that no choleraic effluvia will pass off, or that the choleraic particles passing into the ground may not develop there, as Pettenkofer supposes is the case? I know of no facts to enable us to decide, and I do not think we ought at present to form an opinion on the probability of mischief arising in this way, but it should, at any rate, make us still more urgent in the use of disinfectants to all discharges.

Again, as to disposal in the earth, if Pettenkofer is correct, a loose moist earth is the place where the supposed germ of cholera acquires its power. The last place we should put a choleraic discharge would be the earth; and there would be even an argument against the use of the earth plan of dealing with sewage. Still, as there is much to be said against Pettenkofer's views, and as in small towns and villages there is only the alternative of allowing the discharges to pass into cesspools or streams, or to be disposed of in the earth, I think the safest course is to deeply bury all disinfected discharges, care being taken to place them at a distance from houses and from sources of water supply.

That linen and bedding should be carefully disinfected, needs no argument.

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* That these may be so, in a particular way, I have rendered probable in my Report on Cholera in Southampton (Sixth Report of the Medical Officer to the Privy Council, p. 251); but still there is very little evidence on this point.

4. The occasional, perhaps frequent, introduction by water seems certain. It is a good plan always to change the source of supply when practicable; to use rain water if no other fresh source is procurable; to boil, and filter through animal charcoal, and to use also potassium permanganate.* It remains yet uncertain whether a water which gives cholera is always chemically impure, or whether the choleraic matter may be in so small a quantity as to be absolutely indetectable. In the two cases I have examined in which the water was the cause, it was highly impure.

5. The freest ventilation is desirable; and there are many instances of the good effect of this. This can only be explained if the poison is in the air, and then is received into the body. Therefore, besides ventilation, systematic aerial disinfection should be carried on, especially with nitrous acid.

6. Connected also with the presence of the poison in the air is the very singular way in which cholera is sometimes localised. The localisation is often as marked as in yellow fever, and may be confined to a very small area. At other times, in India, the "tainted district" may be of some extent. From this fact of localisation arises the important rule of always leaving the locality when practicable, and in a large town of clearing out the house where cholera has happened. In India the present rule is to march the men and encamp in a healthy spot at some little distance, changing the encamping ground from time to time. On the whole, this has acted well, and should be adhered to, though occasionally it has failed, generally, however, I believe, from error in choice of locality. The men should be tented; the tents should be well ventilated, and often struck and repitched; an elevated spot should be chosen, and damp and low soils and river banks avoided. An order by Lord Strathnairn has laid down with precision the exact steps to be taken by a regiment when cholera threatens. This rule of marching out must, of course, be subject to some exceptions.† It has been advised that it should not be done in the rainy season in India. This must depend on the locality. I have been informed that it has sometimes answered well, even in heavy rains; but in other cases the rains may be too heavy. No absolute rule can be laid down; but the circumstances which are allowed to set aside the grand rule of evacuation of a tainted place should be unequivocal.

In connection with change of locality, the opinions of Pettenkofer should be borne in mind. Pettenkofer believes, that of all conditions, the effect of soil is the most important.‡ If I do not misinterpret him, he considers that,

* In the very able Report on Epidemic Cholera in the United States Army (Circular No. 5, War Department; Surgeon-General's Office, Washington), is what appears to be a good instance of the effect of changing the supply. At New Orleans rain, and in some cases distilled water, was supplied, instead of river water, with the apparent effect of checking the spread (p. xvii.).

† Dr Moorhead, one of our greatest authorities on Indian diseases, has lately expressed a strong opinion against the marching out and the treatment of men in tents, which he thinks will increase the fatality. I have the greatest respect for Dr Moorhead's opinion, but I believe the bulk of the evidence is decidedly in favour of evacuating the locality. This is no new opinion of mine; ever since I saw the plan adopted by the Burmese in 1843, as noted in my work on Cholera published in 1847, I have been persuaded of the great advantage of leaving the choleraic district; and all the evidence I have seen since has convinced me that though, like every other measure, it will not always succeed, it is the best to adopt if it is done judiciously. The Fourth Bengal Sanitary Report, just published, gives some further evidence. Dr Cunningham has evidently stated the case very candidly (p. 114), and the impression made on his mind is favourable to the plan even in the year 1867, when it has been said to have failed.

‡ The opinions of Pettenkofer have been supported by many examples of the prevalence of cholera in certain geological formations, and its absence from others. Pettenkofer has also lately investigated, with great acumen, the case of Lyons, in which city, although there was an outbreak in 1854, there has been, on the whole, a singular immunity, although the disease must have been often imported (Zt. für Biol. band iv. p. 490, 1868). All the facts he can collect convince Pettenkofer of the absolute necessity of the participation of the soil (*op. cit.* pp. 441, 442), and of the error of ascribing any effect to contaminated water. Other writers (whose papers are chiefly published in the same journal, Zt. für Biol.) have adduced other instances; but, on

without the participation of the soil, no epidemic of cholera is possible. Five things must, he believes, concur—1. A loose porous soil, permeable by air and water; 2. A change in the level of the subsoil or ground water, the dangerous time being the period of the sinking of the water after a previous rise; 3. Organic matters (excrements especially) in the soil; 4. A germ (the cholera germ) brought into the ground by the discharges from choleraic persons; then to these conditions must be added, 5. The presence of persons who can take cholera. If these rules be correct, it becomes of importance to consider particularly the nature of the soil where the fresh camps are to be placed, and to select the perfectly dry and, if possible, pure, impermeable, and uncontaminated soils, and to prevent the cholera discharges from percolating through the ground.

7. Men sick from cholera are also best treated in well-ventilated tents, whenever the season admits of it. Even in cold countries, up to the end of October or the middle of November, tents can be used if properly warmed. In India it should be a rule to treat every cholera patient in a tent, as far as circumstances permit it.*

Internal Causes.—General feebleness of health gives no predisposition, nor is robust health a safeguard; some even have thought that the strongest men suffer most. Great fatigue, and especially if continued from day to day, greatly predisposes; of this there seems no doubt.† No certain influence has yet been traced to diet, although it has been supposed that a vegetable diet and alkalinity of the intestinal contents may predispose. It does not appear that insufficient diet has any great effect, though there is some slight evidence that scurvy increases the mortality, and perhaps the predisposition.‡ The strictest temperance does not preserve from attacks; but every one agrees that spirits are no protection, and that debauchery increases liability.

Of pre-existing diseases, it has been supposed that cardiac affections and

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the other hand, there are several notices of soil adverse to this view, and it does not seem, as expressed in the absolute terms employed by Pettenkofer, consistent with all the known facts of the spread of cholera. That soil (in respect of permeability and temperature) has an influence, is undoubted, and that the ground water is in some cases an important agent in aiding in some way the spread of cholera, seems very likely, but I think the soil cannot be considered an essential factor, though in some cases it is a very important one. The effect of Pettenkofer's view is to admit the portability of cholera, but to deny its communicability from person to person (either directly or remotely), until it has undergone some kind of change and development in the ground.

* Great importance has been attached to the meteorological conditions attending outbreaks of cholera; they do not appear to be very important, except in two or three cases.

1. *Temperature.*—A high temperature favours the spread by increasing the putrefaction of the stools, and by augmenting generally the impurity of the air. When cholera has prevailed at a low temperature (it has been severe at a temperature below freezing), the drinking water has possibly been the cause.

2. *Pressure* has no effect. The old observation of Prout, that the air is heavier in cholera epidemics, has never been confirmed.

3. *Moisture in Air.*—Combined with heat, this seems an accessory cause of importance, probably by aiding transmission. Moisture in the ground has always been recognised as an aiding cause of great importance.

4. *Dryness of Air* seems decidedly to check it.

5. *Rain* sometimes augments, sometimes checks it. This, perhaps, depends on the amount of rain. A very heavy rain is a great purifier.

6. *Movement of Air.*—It is certainly worst in the stagnant atmospheres, as in the cases of all the specific poisons.

7. *Electricity* is not known to have any effect. This was particularly examined by Mr Lamont in Munich, one of the most celebrated physical philosophers of our time, but with entirely negative results.

8. *Ozone* has no effect, either in its presence or absence. (Schultze, Voltotine, De Wethe, Lamont, Strambio, Wunderlich.)

† There are many instances of the effects of long marches. See Orton, Lorimer, and Thom, quoted in Brit. and For. Med.-Chir. Rev., July 1848, pp. 85–87.

‡ For some evidence as to scurvy, see Pearce and Shaw on the cholera of the jail at Calicut. —*Madras Medical Journal,* July 1863.

pulmonary emphysema predispose; the evidence is very unsatisfactory. If Beale's observations be correct, post-mortem examinations often show previous affection of the villi and mucous membranes of the intestines generally; but it is very desirable there should be more proof of this.

Diarrhœa predisposes, and any causes which lead to diarrhœa, especially impure water, dietetic errors, &c., should be carefully looked after.

With regard to prophylactic measures (except in respect to proper diet, free ventilation, and pure water), nothing has been yet made out. Quinine has been recommended, and should certainly be given, especially in malarious countries, as it is a fact that the choleraic poison and malaria may act together, and even give a slight periodical character to choleric attacks, which is never seen in non-malarious districts, and is therefore merely grafted on cholera. Peppers, spices, &c., have been used; but I am not aware of any good evidence. All diarrhœa should be immediately checked, and this is well known to be the most important point connected with the prevention of the internal causes. The universal order in India is, that any man going twice in one day to the latrine should report himself; and non-commissioned officers are usually stationed at the latrines to watch the men. The reason of this rule should be fully explained to the men. In two attacks of cholera in India, I found it almost impossible to get the men to report themselves properly; the slight diarrhœa of early cholera is so painless that they think nothing of it.*

Typhus Exanthematicus (*Spotted Typhus*).

External Cause.—An animal poison, origin unknown, but communicable from person to person, probably through the excretions of the skin and lungs floating in the air. Not known to be communicated by water. Its spread and its fatality are evidently connected with overcrowding and debility of body from deficient food. That it can be produced by overcrowding is yet uncertain.† The preventive measures may be thus shortly summed up:—Adopt isolation‡ of patients; use the freest ventilation (5000 to 6000 cubic feet per head per hour or more); evolve nitrous acid and chlorine fumes; thoroughly fumigate with sulphurous acid, heat (to 240° Fahr.), wash, and expose to air all bedding (including mattresses) and clothes. This last point is extremely important. In fact, it may be said that, for the prevention as well as treatment of typhus, the cardinal measures are abundance of pure air and pure water. Whenever practicable, treat all typhus patients in tents, or wooden huts with badly-joined walls, not in hospitals. Fumigate tents and scrape and limewash huts, and remove earth from time to time from the floors. A number of typhus patients should never be aggregated; they must be dispersed; and if cases begin to spread in an hospital, clear the ward, and then, if the disease continues, the hospital itself; then wash with chloride of lime, and then limewash or scrape walls and floors, and thoroughly fumigate with nitrous acid. It has been often shown that even exposure to weather, bad diet, and insufficient attendance, are less dangerous to the patients than the aggregation of cases of typhus (see especially p. 328).

* I have taken several points from Mr Dickinson's useful little pamphlet on the "Hygiene of Indian Cholera," 1863.

† For some evidence on this point, see Murchison on Fevers, and a paper in the "Medical Times and Gazette," July 1859.

‡ By the term isolation, I imply the placing a patient in a separate building, not in another room in the same building; in the case of smallpox, typhus, and scarlet fever, this partial isolation, though sometimes successful, cannot be depended upon. If a room must be chosen in the same building, choose the top story, if a good room can be there found.

Internal Causes.—A special condition of body is necessary, as in the case of smallpox, and one attack protects to a great extent from another. The nature of the internal condition is unknown; but general feebleness from bad diet, overwork, exhaustion, and especially the scorbutic taint, greatly increase the intensity of the disease in the individual, and perhaps aid its spread. These conditions, then, must be avoided. But the strongest and best health is no guarantee against an attack of typhus.

*Bubo or Oriental Plague (Pali Plague in India).**

The preventive measures should be the same as in typhus, to which this disease shows great analogy. The history of the plague at Cairo (from which it has been now banished for many years, simply by improving the ventilation of the city),† and the disappearance, after sanitary improvements, of the Pali plague in India, and its recurrence on the cessation of preventive measures, show that, like typhus, the bubo plague is easily preventible. Elevation, as in so many other specific diseases, has a considerable effect; the village of Alum Dagh, near Constantinople (1640 feet above the sea), and freely ventilated, has never been attacked; the elevated citadel of Cairo has generally been spared, and when Barcelona was attacked, the elevated citadel also escaped.

Typhoid or Enteric Fever.

External Cause.—A poison of animal origin; one mode of propagation is by the intestinal discharges of persons sick of the disease; other modes of origin and transmission are not disproved. There is doubtless a frequent transmission of the disease by the diarrhœa of mild cases which are often not diagnosed. There is some evidence that persons considered convalescent may carry the disease,‡ but it is possible that this may have been owing to badly washed clothes. The mode of entrance into the body is both by air and water. (See pages 72 and 109.) As means of arresting the disease, isolate patients; receive all evacuations (fæces and urine) into vessels strictly kept for one sick person; place zinc chloride, or ferrous sulphate, or carbolic acid, &c., in the vessels; never empty any evacuation into a closet, sewer, or cesspool; bury it several feet deep, and mix it well with earth. Fumigate, and heat to 240° Fahr., all clothes and bedding. Use nitrous acid fumes in the wards. As means of prevention, attend especially to the purity of the drinking water, and to the disposal of sewage: although the origin of typhoid merely from putrefying non-typhoid sewage is not considered at present to be probable, it is not disproved, and it is certain that the disease may spread by the agency of sewers and fæcal decomposition. A single case of typhoid fever should at once be held to prove that something is wrong with the mode of getting rid of the excretions.

Internal Causes.—As a first attack preserves in a great measure from a second, a peculiar condition of body is as essential as in smallpox; and look-

* The Pali plague (Maha Murree), which was most common in Rajpootana, was evidently propagated by the filthy habits of the inhabitants (see Ranken and others), and was some years ago almost entirely got rid of by sanitary measures. Subsequently, these were neglected, and the disease returned. It is now, I believe, again greatly lessened. Hirsch has pointed out that the Pali plague differs from the Egyptian plague, in having a marked lung disease, and in this it resembles the black death of the fourteenth century, with which Hirsch, in fact, considers it identical.

† Stamm, in Pappenheim's "Beiträge," 1862–3, p. 80. The measures adopted in Cairo were levelling some hillocks, which stopped the air from blowing over the city, filling up some marshes, and adopting a better mode of burial. The peculiar sepulture customs of the Copts have indeed even been assigned as the sole cause of the origin of plague.

‡ Gietl. Die Ursachen der enterischen Typhus in München, 1865, pp. 74 and 94.

ing to the special effect produced on Peyer's patches, and to the fact that at the period of life when these patches naturally degenerate, the susceptibility to typhoid fever materially lessens, or even ceases, it seems possible that the internal cause or necessary second condition is the existence of these patches, the structures in which are brought into an abnormal state of activity by the direct or indirect action of the poison on them. The other internal causes are anything which causes gastro-intestinal disorder, such as bad water, and general feebleness.

Relapsing Fever.

No preventive measures have been yet pointed out, to my knowledge, but the occurrence of the disease in times of famine seems to indicate that feebleness and inanition are necessary internal causes.

Bilious Remittent Fevers.

Under this vague term, a disease or diseases, which in many points are like relapsing fever, but yet are not identical (Marston), have been described as occurring especially in Egypt (Griesinger), and in the Levant generally. It has been lately described by Drs Marston and Boileau* at Malta. The exact causes are not known ; but in some of the writings of the older army surgeons, the fevers which are produced by foul camps (in addition to typhoid) appear to have a close resemblance to the bilious remittent fevers of the Mediterranean. They appear to be connected with bad sanitary conditions, but their exact causation is not clear.

Cerebro-Spinal Meningitis.

This disease, which has occasionally been noticed in France, and especially among soldiers for the last forty years, has within the last few years appeared in several parts of Germany, and a few cases among civilians have occurred in England. It seems to depend on a specific agent, but very little is yet known about it. It does not appear to be contagious. No preventive measures can be at present suggested.

The Eruptive Fevers.

Smallpox is guarded against in the army by repeating vaccination in the case of recruits, and by occasional re-vaccination of all the men in a regiment. In Dr Balfour's statistical reports, great attention is always paid to this important point, and the evidence from foreign armies prove the necessity of careful re-vaccination.

If the disease does occur, the use of chlorine, iodine, and nitrous acid thrown up into the air, should not be forgotten, in addition to all usual measures of isolation (in separate buildings) and sanitary appliances.

In the case of scarlet fever and measles, nothing definite is known with regard to prevention, except that a good sanitary condition seems to lessen their intensity, and probably their spread. The evidence with regard to belladonna in scarlet fever is contradictory, but on the whole unfavourable. When the disease is actually present, fumigations, as in smallpox, should be used. All the discharges should be disinfected, and the skin well rubbed over with oil and a little weak carbolic acid. (See page 365.)

The most difficult case is when either measles or scarlet fever appears on board ship, and especially if children are on board. If the weather permit,

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* Army Med. Reports, vols. iii. and viii.

the best plan is then to treat all patients on the upper deck under an awning. If this cannot be done (and scarlet fever patients must not be exposed to cold), they must be isolated as much as possible, and the place constantly fumigated. Both in scarlet fever and smallpox there is some evidence to show that the incubative period may be very long.*

Perhaps, in the present state of evidence, it might be desirable to try the prophylactic effects of belladonna on board ship, directly the first case occurs.

Erysipelas (*Hospital or Epidemic*).

External Cause.—It is well known that in the surgical wards of hospitals erysipelas occasionally occurs, and then may be transmitted from patient to patient. The exact causes of its appearance have not been made out, but it is evidently connected with overcrowding and impure air. Moisture of the floors, causing constant great humidity of air, has also been supposed to aid it. It is much more common in fixed hospitals than in tents and huts, and indeed is exceedingly rare in the two latter cases. The agencies or agent can scarcely be supposed to be other than putrefying organic matter and pus cells passing into and accumulating in the air. They or it would appear to be really generated during the process of suppuration of wounds, and at present the production of a transmissible agent in this way is one of the best examples we have of the origin of a contagion *de novo*. It is remarkable that pus cells derived from purulent sputa do not cause erysipelas in medical wards, but this may be from a want of open wounds to give the necessary personal condition.

When hospital erysipelas has once appeared in a ward, nothing will avail except complete clearance of the ward, scraping the floors, and often the walls, washing with chloride of lime, and then with solution of caustic lime, and thorough fumigation with chlorine and nitrous acid alternately. The erysipelatous cases should be placed in well-ventilated tents. If this cannot be done, then nitrous acid and chlorine fumigations must be constantly used in the wards, charcoal trays be placed round the bed of the erysipelatous patient, and excessive ventilation employed.

Considering the undoubted beneficial influence of tent life, it may be a question whether, even in civil life, hospitals which possess gardens should not, during the summer, treat their surgical cases with suppurating wounds in the tents.†

Of course, extreme care in conservancy of wards or tents, the immediate removal of all dressings, great care in dressing wounds, so that neither by instruments, sponges, lint, or other appliances, pus cells or molecular organic matter shall be inoculated, are matters of familiar hospital hygiene. The use of carbolic acid, as introduced by Professor Lister, will, it is hoped, greatly lessen the chances of spread in the case of erysipelas as well as of hospital gangrene.

Internal Causes.—Nothing, I believe, is known on this point, except that there must be some abrasion or wound of the surface or of the passages near the surface, as the vagina or throat. The erysipelas commences at the point of abrasion. If there is no open wound, the atmospheric impurity seems to have no bad effect on the persons who are exposed to it, but it would be interesting to know if some forms of internal disease are not produced. Is it

* See a case by Bryson (Trans. Soc. Science Assoc. 1862, p. 677), for a case in which the incubative period of smallpox was thirty-one days. In scarlet fever it is sometimes even longer.

† See Hammond's Hygiene, 1863; Kraus' Das Kranken und Zerstreuungs-System, 1861; and a Report on Hygiene, by the author, in the "Army Medical Report," for 1862, for the effects of tents on erysipelas and hospital gangrene.

possible that some forms of tonsillitis and diphtheritic-like inflammation of the throat may be caused in this way, although there is no solution of continuity?

Hospital Gangrene.

Almost the same remarks apply to hospital gangrene as to erysipelas. One of the most important facts which has been pointed out by many writers, and which has been thoroughly proved by the American and the Italian wars, is that perfectly free ventilation prevents hospital gangrene.

Hammond, the late Surgeon-General of the United States Army, declares* that only one instance has come to his knowledge in which hospital gangrene has originated in a wooden pavilion hospital, and not one which has occurred in a tent. Kraus also, from the experience of the Austrians in 1859, states that it never could be discovered that gangrene originated in a tent. On the contrary, cases of gangrene at once commenced to improve when sent from hospital wards into tents. On the other hand, the tenacity with which the organic matters causing the gangrene adhere to walls is well known.

The measure to be adopted in wards when hospital gangrene occurs, and the ward cannot be at once evacuated, are the same as for erysipelas.† It is not necessary to do more than allude to the undoubted transference by dirty sponges, &c., and to the beneficial effects of carbolic acid dressings.

SECTION II.

VARIOUS NON-SPECIFIC DISEASES.

Dysentery and Diarrhœa.

At present there is no evidence that the dysentery arising from various causes has different anatomical characters, or runs a different course, except perhaps in the case of malarious dysentery. The chief causes are—

1. *Impure Water* (pages 66–69).—Both Annesley and Twining have directed attention to this cause, in their accounts of Indian dysentery. It is scarcely possible that, with common attention, this cause should not be discovered and removed.

2. *Impure Air.*—The production of dysentery and diarrhœa from the effluvia of putrefying animal substances is an opinion as old as Cullen, and probably older; and there seems little doubt of its correctness. The gases and vapours from sewers and from sewage on land also will, in some persons, cause it (pages 108, *et seq.*); and also effluvia from the foul bilge-water of ships.‡ On the other hand, very disagreeable effluvia from many animal substances, as in the case of bone-burners, fat-boilers, &c., do not seem to cause diarrhœa. In India there appears to be a decided relation between the prevalence of dysentery and overcrowding and want of ventilation in barracks; massing a large number of men together is certainly an accessary cause of great weight.§

The air from very foul latrines has caused dysentery in numerous cases

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* Hygiene, p. 397.

† With regard to pyæmia, observations show that one of the external causes is fœtid organic emanations. Spencer Wells ("Med. Times and Gazette," 1852) states, that in 1859 the mortality from pyæmia was great in some wards over a dissecting room. On removing all the cases after operation to the opposite side of the building, pyæmia almost disappeared. Other similar cases are on record.

‡ Fonssagrives (Traité d'Hygiène Navale, p. 60) records a good case of this kind. It commenced after a gale at sea had stirred up the bilge, and on clearing it out, the attack ceased.

§ Wood on the Health of European Soldiers in India, 1864, p. 45, *et seq.*

Pringle, and many other army surgeons, record cases.* In war this is one of the most common causes. The occasional production of dysentery from sewage applied to land, seems to me to be proved by Clouston's observations on the causes of the attack of dysentery in the Cumberland Asylum ("Medical Times and Gazette," June 1865). Still sewage matter has been often applied in this way without bad effects. In Dr Clouston's case the sewage was 300 yards from the ward where the dysentery occurred. Calm and nearly stagnant nights, or with a *gentle* movement of air from the sewage towards the ward, were the conditions which preceded most of the attacks.

Of all the organic effluvia, those from the dysenteric stools appear to be the worst. Some evidence has been given to show that dysentery arising from a simple cause (as from exposure to cold and wet), when it takes on the gangrenous form, and the evacuations are very fœtid, produces dysentery in those who use the latrines, or unclean closets, into which such gangrenous evacuations are passed. If correct, this is a most interesting point, as it seems to show the origin of a communicable poison *de novo*. Possibly, in all these cases, effluvia, or organic matters, or particles disengaged from the putrefying evacuations, act at once on the anus, and the disease then spreads up by continuity.

There is some reason, also, to think that retaining dysenteric stools in hospital wards spreads the disease; and, perhaps, in this case, the organic particles floating up may be swallowed, and then act on the mucous membrane of the colon. In the epidemic of dysentery in Sweden in 1859, there was good evidence to show that it spread by means of the diarrhœal and dysenteric evacuations.†

In addition to removal of the sources of all these effluvia, fumigations with nitrous acid, and with chlorine, should be practised in all dysenteric wards, as in the case of typhoid fever, the stools must be mixed with disinfectants, and immediately removed from the wards and buried.

3. *Improper Food.*—Any excess in quantity, and many alterations in quality (especially commencing decomposition in the albuminates, and perhaps, the rancidity of the fatty substances) cause diarrhœa, which will pass into dysentery (see the chapter on Food). But the most important point in this direction is the production of scorbutic dysentery. A scorbutic taint plays a far more important part in the production of dysentery than is usually imagined, and there is now no doubt that the fatal dysentery, which formerly was so prevalent in the West Indies, was of this kind. Much of the Indian dysentery is also often scorbutic.

4. *Exposure to Cold and Wet.*—Exposure to cold, especially after exertion, and extreme variations of temperature, have been assigned as the chief cause of dysentery by numerous writers;‡ great moisture has been assigned by some writers (Twining, Annesley, Griesinger) as a cause; and great dryness of the air by others (Mouat); while a third class of observers have considered the amount of moisture as quite immaterial.

Hirsch,§ after summing up the evidence with respect to temperature with

* Sir James M'Grigor, Vignes (who gives many cases from the French experience in the Peninsula), Chomel, Copland; see also the "Dic. des Sciences Méd." Art. *Dysenterie*. D'Arcet ("Ann. d'Hygiène," vol. xii. p. 390) records a good case, in which a whole regiment was affected in the Hanoverian war, from having used too long the same trench as a latrine. The disease disappeared when another was dug.

† "British and Foreign Med.-Chir. Rev." Jan. 1866, p. 140.

‡ A few only can be noted:—Stoll, Zimmermann, Huxham, Durandeau, Willan, Irvine, James Johnson, Annesley, Bampfield, Morehead, Vignes, Fergusson, &c. Fergusson says—"True dysentery is the offspring of heat and moisture; of moist cold in any shape after excessive heat. Nothing that a man can put into him would ever give him true dysentery."

§ Handbuch der Historisch-Geograph. Pathol. band. ii. p. 234.

great care, decides, that sudden cold after great heat is merely a "*causa occasionalis*,"* which may aid the action of the more potent causes of dysentery. This, probably, is the true reading of the facts. The amount of moisture in the atmosphere would appear to be a matter of no moment.

Although we cannot assign its exact causative value, the occurrence of chill is, of course, as a matter of prudence, to be carefully guarded against; and especially chills after exertion. It is when the body is profusely perspiring, and is then exposed to cold, that dysentery is either produced, or that other causes are aided in their action. In almost all hot countries chilling of the abdomen is considered particularly hurtful, and shawls and waist-bands (kummerbund of India) are usually worn.†

5. Malaria has been assigned as another cause; and it was noticed, especially by the older writers, that the dysentery was then often of the kind termed "*Dysenteria Incruenta*"—the stools being copious, serous, and with little blood; in fact, a state somewhat resembling cholera.

Very great difference of opinion has prevailed in regard of this opinion.‡ Possibly the "malarious dysentery" is in part connected with the use of marsh water. More evidence is desirable, certainly, with regard to this point; but it seems probable, from the observations of Annesley and Twining, that marsh-water has an effect in this direction.

Liver Diseases (*Indian*).

The production of diseases of the liver is so obscure, and so many states of hepatic disorder are put together under the term "hepatitis," that it is impossible to treat this subject properly without entering fully into the question of causes. But, as this could not be done here, I must content myself with a short summary of the preventive measures which appear to be of the greatest importance.

I have long been convinced that many cases of hyperæmia, bilious congestion, and enlargement of the liver, with increase of cell-growth and connective tissue (but without tendency to abscess), and enlargement and partial fatty degeneration of the liver cells, are caused simply by diet.§ I had a good opportunity of observing this on landing in India in 1842 with an European regiment,|| and the experience of more than twenty years has made me certain that the observation was correct.

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* The so-called "hill diarrhœa," which was formerly prevalent on some of the hill sanitaria in India, especially on the spurs of the Himalayas, has been attributed to the effect of cold and moisture, and sudden changes of temperature. But, as remarked by Dr Alexander Grant, many hill stations have these atmospheric conditions without having any hill diarrhœa. I learn from some gentlemen who have paid much attention to this subject, that there is great reason to suppose the hill diarrhœa to be entirely unconnected with either elevation or climate. In some cases it has been clearly caused by bad water; in other cases, its exact causes remain unexplained. Of late years it has lessened in amount at all stations, and will probably disappear.

† It is a remarkable circumstance, that in temperate climates the most common months for dysenteric epidemics are the hot months—June to September. Taking North America, and Northern and Western Europe, Hirsch has assembled 546 outbreaks. Of these, 176 occurred in summer; 228 in summer and autumn; 107 in autumn; only 16 in spring; and 19 in winter. This does not look as if cold had any effect. The heat of summer is far more influential.

‡ The very varying opinions are given very fully by Hirsch. Morehead's great authority is altogether against the presumed action of malaria; but, possibly here, as in many other cases, we shall have to draw a complete distinction between malarious and non-malarious dysentery.

§ In the great and admirable works of Ranald Martin and Morehead, the influence of diet in producing liver affections, though alluded to, has been passed over much too lightly. Annesley, on the other hand, has fully recognised the immense influence of diet (vol. i. p. 192).

|| Remarks on the Dysentery and Hepatitis of India, 1846, p. 228.

Very similar opinions have been expressed by Macnamara,* and Norman Chevers has also pointedly alluded to this subject.†

The food supplied to the soldier in India errs in two ways: it is too much in quantity, especially when the amount of exercise is limited. Macnamara has calculated that each European soldier in Bengal consumed (at the time he wrote in 1855) 76 ounces of solid (*i.e.*, water-containing) food daily, so that there must have been an excess of all the dietetic principles. Then, in every case, there was added to this a very large amount of condiments (spices and peppers), articles of diet which are fitted for the rice and vegetable diet of the Hindu, but are particularly objectionable for Europeans. In the West Indies, where the diet has never been so rich in condiments, liver diseases have always been comparatively infrequent.

Lately, some orders for improving the cooking in India have been issued by Lord Strathnairn (see section on India), and if these are carried out, and if medical officers would thoroughly investigate the quantity of food taken by the men, and compare it with their work, and examine into the cooking, it is quite certain that many cases of dyspepsia and hepatitis would be prevented.

In cases not simply of hyperæmia and bilious congestion, but of abscess, it is probable that a certain number are consecutive to dysentery, and are caused by the absorption of putrid matters from the intestine,‡ which are arrested by the liver, and there set up suppuration. There is no true pyæmia or inflammation of the vena portæ as a rule. When caused by phlebitis or special affection of the vena portæ, the suppuration is in the course of the vena portæ, or at any rate commences there. The reason why some cases of dysentery cause abscess and others do not, is uncertain. The prevention of this form of abscess is involved in the prevention of dysentery.

In other cases of abscess, however, there is no antecedent dysentery, but there are collections of pus or fœtid debris somewhere else, which act in the same way. There are, however, other cases in which no such causes have been pointed out, and the genesis of abscess remains quite obscure. Much effect has been attribnted to the influence of sudden changes of temperature; to the rapid supervention of an exceedingly moist and comparatively cold air on a hot season, whereby the profuse action of the skin is suddenly checked; and to the influence of malaria. But the extraordinary disproportion of cases of abscess in different parts of the world seems to negative all these surmises.

One fact seems to come out clearly from Mr Waring's observations, viz., that recent arrival in India is favourable to the occurrence of abscess, and that (all kinds of abscesses being put together) 50 per cent. occur in men under three years' service. No length of residence, however, confers perfect immunity. It would be very important to determine whether the effect of recent arrival is marked, both in cases of abscess consecutive, and in those anterior to dysentery.

It is possible, also, that some entozoic influence may be at work, especially in some parts of India, and hydatid disease of the liver or other diseases of the same class may be more common than is supposed.

In the absence of perfect knowledge, great care in preserving from chills.

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* "Indian Annals," 1855. Dr Macnamara found a most extraordinary amount of fatty degeneration of the liver.

† "Health of European Troops in India," Indian Annals, 1858, p. 109: it is particularly recommended that this chapter should be carefully perused.

‡ It is, however, remarkable how many cases of dysentery occur without producing hepatic abscess; still our general knowledge of the causation of disease makes it highly probable that dysentery acts in this way. Is it the sloughing dysentery which is followed by hepatic abscess?

and proper diet, are the only preventive measures which can be suggested for primary hepatic abscess.

Insolation. (*See page* 463.)

Under this convenient term, a number of cases are put together which seem to be produced by one or more of the following causes :—

External Causes.—1. Direct rays of the sun on the head and spine. Adopt light coverings, covered with white cotton; permit a good current of air between the head and the covering, and use a light muslin or cotton rag, dipped in water, over the head under the cap. 2. Heat in the shade, combined especially with stagnant and impure air. In houses (and men have been attacked with insolation both in tents and barracks) means can always be taken to move the air, and thus to keep it pure, even if it cannot be cooled. In tents the heat is often exceedingly great, simply from the fact that there is not sufficient movement of air; in the tropics a simple awning is much better than tents, and if the awning is sloped a little, the top of the slope being towards the north, the movement of air will be more rapid than if the canvas be quite flat. But in the dry season, in the tropics, the men should sleep in the open air in all non-malarious districts, when they are on the march or in campaigns.

The general prophylaxis has been thus summed up by Professor Maclean ("Reynolds' System of Med." vol. ii. p. 157) :—"Men will bear a high temperature in the open air with comparative impunity, provided (*a.*) it is not too long continued; (*b.*) that the dress be reasonably adapted to the temperature; (*c.*) that the free movement of the chest be not interfered with."

Internal Causes.—It is only known that spirit drinking, even in moderation, powerfully aids the external causes of insolation; even wine and beer probably have this effect. Tea and coffee, on the other hand, probably lessen the susceptibility.

A full habit of body, or any tendency to fatty heart or emphysematous lungs, have been supposed also to predispose.

It seems certain that any embarrassment of the pulmonary circulation aids the action of the heat, and therefore the most perfect freedom from belts and tight clothes over the chest and neck is essential.

Great exhaustion from fatigue aids the action, either from failure of the heart's action or want of water. In this case diffusible stimuli, such as ammonia, tincture of red lavender, tincture of cardamoms, &c., with strong coffee, are the best preventives. Spirits should not be given unless the exhaustion be extreme, and the diffusible stimuli cannot be obtained. A small quantity in hot water may then be tried.

Cold baths, and especially cold douching to the head and spine, are most useful as preventive as well as curative measures.

Phthisis Pulmonalis.

It seems to me highly probable, that in respect of causes, we must distinguish between those usually rapid cases of phthisis which arise from hereditary constitutional causes, or from the influence of exanthemata (especially measles), or of typhoid, or other fevers, and which run their course with implication of several organs at an early stage, and the more chronic forms of phthisis, in which the lung in adults is the first seat of the disease, and other organs are secondarily affected. Probably several distinct diseases are confounded under this one term of phthisis, and it is therefore not possible at present to trace out their precise origin.

Taking only the common cases of subacute or chronic phthisis, it has been

already intimated that most European armies have been found to furnish an undue proportion of such cases.*

A few years ago much influence was ascribed to food as a cause of phthisis; the occurrence of a sort of dyspepsia as a forerunner (though this does not seem very common), and the great effect of the treatment by diet (by cod-liver oil), seemed to show that the fault lay in some peculiar malnutrition, which affected the blood, and through this the lungs.

Probably there is truth in this; but of late years the effects of conditions which influence immediately the pulmonary circulation and the lungs themselves have attracted much attention. The effect of want of exercise (no doubt a highly complex cause, acting on both digestion and circulation), and of impure air, have been found to be very potent agencies in causing phthisis, and conversely, the conditions of prevention and treatment which have seemed most useful are nutritious food and proportionate great exercise in the free and open air. So important has this last condition proved to be, that it would appear that even considerable exposure to weather is better than keeping phthisical patients in close rooms, provided there be no bronchitis or tendency to pneumonia or pleurisy.

Three points, then, are within our control as regards phthisis—arrangement of food, exercise, and pure air.

The food should contain a good deal of the nitrogenous and fatty principles if phthisis is apprehended. Milk has been long celebrated, and lately the koumiss of Tartary has obtained a great reputation in Russia as an agent of cure.

Exercise is of the greatest importance, and it would seem quite clear that this must be in the open air. The best climates for phthisis are perhaps not necessarily the equable ones, but those which permit the greatest number of hours to be passed out of the house.

In the house itself, attention to thorough ventilation, *i.e.*, to constant, though imperceptible movement of the air, is the point to be attended to.

In the case of soldiers, it must also be seen that no weights or straps impede the circulation of blood through the lungs and heart.

The effect of a wet subsoil in the causation of phthisis (see p. 293 for Buchanan's observations) must not be overlooked. Whatever may be the exact amount of truth, we are bound to act as if it were certain.

That the syphilitic disease of the lungs has sometimes a completely phthisical character is tolerably clear, but syphilis will not account for the amount of phthisis in the army. The influence of masturbation in producing phthisis is uncertain.

Scurvy.

The peculiar state of malnutrition we call scurvy is now known not to be the consequence of general starvation, though it is doubtless greatly aided by this. Men have been fed with an amount of nitrogenous and fatty food sufficient not only to keep them in condition, but to cause them to gain weight, and yet have got scurvy. The starches also have been given in quite sufficient amount without preventing it. It seems, indeed, clear that it is to the absence of some of the constituents of the fourth dietetic group, the salts, that we must look for the cause.†

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* See p. 104, and the Sections on Home and Foreign Service. There are two valuable pieces of evidence of phthisical and scrofulous disease being developed in a healthy population from impure air, viz., Mr Morgan's essay on "Phthisis on the West Coast of Scotland" ("Brit. and For. Med.-Chir. Rev."), and the analogous case of Western Canada, given by Mr Mackelcave ("Medical Times and Gazette," Aug. 1868).

† For a good deal of the evidence up to 1841, I beg to refer to a review I contributed on

Facts seem to show with certainty that there is no deficiency of soda or of iron, lime, or magnesia, or of chloride of sodium. Nor is the evidence that salts of potash or phosphoric acid are deficient at all satisfactory. And when we think of the quantity of phosphoric acid which must have been supplied in many diets of meat, and cerealia, which yet did not prevent scurvy, it seems very unlikely that the absence of the phosphates can have anything to do with it.

The same may be said of sulphur. Considering the quantity of meat and of leguminosæ which some scorbutic patients have taken, it is almost impossible that deficiency in sulphur should have been the cause.

By exclusion, we are led to the opinion that if the cause of scurvy is to be found in deficiency of salts, it must be in the salts whose acids form carbonates in the system. For, if we are right in looking to a deficiency in the fourth class of alimentary principles as the cause of scurvy, and if neither the absence of soda, potash, lime, magnesia, iron, sulphur, or phosphoric acid can be the cause (and it is probable it is not so), then the only mineral ingredients which remain are the combinations of alkalies with those acids which form carbonates in the system, viz., lactic, citric, acetic, tartaric, and malic. That these acids are most important nutritional agents no one can doubt. The salts containing them are at first neutral, afterwards alkaline, from their conversion into carbonates; they thus play a double part, and moreover, when free, and in the presence of albumen and chloride of sodium, these acids have peculiar powers of precipitating albumen, or perhaps of setting free hydrochloric acid.* Whatever may be their precise action, their value and necessity cannot be doubted. Without them, in fact, one sees no reason why there should not be a continual excess of acid in the system, as during nutrition a continual excess of acids (phosphoric, sulphuric, uric, hippuric) is produced, sufficient, even when the salts with decomposable acid are supplied, to render all excretions (urinary, cutaneous, intestinal) acid. The only mode of supplying alkali to the acids formed in the body is by the action of the phosphates, which is limited. The only manufacture of alkali in the body is the formation of ammonia. Yet it is not solely the absence of alkali which produces scurvy, else the disease would be prevented or cured by supply of pure or carbonated alkalies, which is not the case.

When, in pursuing the argument, we then inquire whether there is any proof of the deficiency of these particular acids and salts from the diets which cause scurvy, we find the strongest evidence not only that this is the case, but that their addition to the diet cures scurvy with great certainty. They will not, of course, cure coincident starvation arising from deficiency of food generally, or the low intercurrent inflammations which occur in scurvy, or the occasionally attendant purpura, but the true scorbutic condition is cured with certainty.

Of the five acids, it would appear unlikely that the lactic should be the most efficacious. If so, how is it that in starch food, during the digestion of which lactic acid is probably formed in large quantities, scurvy should occur? Is, in such a case, an alkali necessary to insure the change of the acid into a carbonate? How is it that scurvy will occur with a milk diet, though, doubtless, milk is a good, though not perfect preservative?

Scurvy to the "British and Foreign Medico-Chirurgical Review" in that year. The evidence since this period has added, I believe, little to our knowledge, except to show that the preservative and curative powers of fresh meat in large quantities, and especially raw meat ("Kane's Arctic Expeditions"), will not only prevent, but will cure scurvy. Kane found the raw meat of the walrus a certain cure.

* See a notice by the author of this singular property in the "Medical Times and Gazette," 1850. Melsens subsequently directed attention to this point.

Vinegar is an old remedy for scurvy, and acetic acid is known to be both a preventive of (to some extent) and a cure for scurvy. But it has always been considered much inferior to both citric and tartaric acids. Possibly, as in the case of lactic acid, an alkali should be supplied at the same time, so as to enable the acid to be more rapidly transformed.

Tartaric, and especially citric acids, when combined with alkalies, have always been considered to be the antiscorbutic remedies, *par excellence*, and the evidence on this point seems very complete.*

Of malic acid little is known as an antiscorbutic agent, but it is well worthy of extended trials.

Deficiency of fresh vegetables implies deficiency in the salts of these acids, and scurvy ensues with certainty on their disuse. Its occurrence is, however, greatly aided by accessary causes, especially deficiency in food generally, by cold and wet, and mental and moral depression.

The preventive measures of scurvy are, then, the supply of the salts of citric, tartaric, acetic, lactic, and malic acids, and of the acids themselves, and perhaps in the order here given, and by the avoidance, if it can be done, of the other occasional causes.

Experience seems to show that the supply of these acids in the juices of the fresh succulent vegetables and fruits, especially the potato, the cabbage, orange, lime, and grape, is the best form. But fresh fruits, tubers, roots, and leaves are better than seeds. The leguminosæ, and many other vegetables, are useless.

Fresh, and especially raw meat is also useful, and this is conjectured to be from its amount of lactic acid; but this is uncertain.

The dried vegetables are also antiscorbutic, but far less so than the fresh; and the experience of the American War is not so favourable to them as might have been anticipated. Do the citric and other acids in the dried vegetables decompose by heat or by keeping? It would be very desirable to have this question settled by a good chemist. We know that the citric acid in lemon juice gradually decomposes. It does not follow that it should be quite stable in the dried vegetables.

The measures to be adopted in time of war, or in prolonged sojourn on board ship, or at stations where fresh vegetables are scarce, are—

1. The supply of fresh vegetables and fruits by all the means in our power. Even unripe fruits are better than none, and we must risk a little diarrhœa for the sake of their antiscorbutic properties. In time of war *every* vegetable should be used which it is safe to use, and, when made into soups, almost all are tolerably pleasant to eat.

2. The supply of the dried vegetables, especially potato, cabbage, and cauliflowers; turnips, parsnips, &c., are perhaps less useful; dried peas and beans are useless. As a matter of precaution, these dried vegetables should be issued early in a campaign, but should never supersede the fresh vegetables.

3. Good lemon juice should be issued daily (1 oz.), and it should be seen that the men take it.

4. Vinegar ($\frac{1}{2}$ oz. to 1 oz. daily) should be issued with the rations, and used in the cooking.

* It is based on a very wide experience, and should not be set aside by the statements of men who have seen only three or four cases of scurvy, often complicated, which happen not to have been benefited by lemon juice. The progress of preventive medicine is checked by assertions drawn from a very limited experience, yet made with great confidence. We must remember that many cases of scurvy are complicated—that the true scorbutic condition, inanition, and low inflammation of various organs, lungs, spleen, liver, and muscles, may be all present at the same time.

5. Citrates, tartrates, lactates, and malates of potash, should be issued in bulk, and used as drinks, or added to the food. Potash should be selected as the base, as there is seldom any chance of the supply of soda being lessened. The easiest mode of issuing these salts would be to have packets containing enough for one mess of twelve men, and to instruct the men how important it is to place them in the soups or stews. Possibly they might be mixed with the salt, and issued merely as salt..

Military Ophthalmia.

The term "military ophthalmia" is often applied particularly to that disease in which the peculiar grey granulations form on the palpebral conjunctiva. But any severe form of purulent ophthalmia spreading in a regiment is often classed under the same heading. Diseases of the eyes are a source of very considerable inefficiency in the army, and even a casual visitor to the Royal Victoria Hospital must be struck by the large number of men he will meet with who have some affection of the eyes. A reference to the Army Medical Reports will also show what great attention is being paid to this important subject by military surgeons, especially by my colleague, Professor Longmore.*

Epidemics of military ophthalmia (grey or vesicular granulations, and rapid purulent ophthalmia), seem to have been uncommon, or perhaps unknown, on the large scale in the wars of the eighteenth century.

The disease, as we now see it, is one of the legacies which Napoleon left to the world. His system of making war with little intermission, rapid movements, abandonment of the good old custom of winter quarters, and intermixture of regiments from several nations, seem to have given a great spread to the disease, and though the subsequent years of peace have greatly lessened it, it has prevailed more or less ever since in the French, Prussian, Austrian, Bavarian, Hanoverian, Italian, Spanish, Belgian, Swedish, and Russian armies, as well as in our own. It has also been evidently propagated among the civil population by the armies, and is one more heritage with which glorious war has cursed the nations.

In some cases, as in the Danish army, it has been absent till manifestly introduced (in 1851); in other instances it has been supposed to originate spontaneously from overcrowding and foul barrack atmosphere, and from defective arrangements for ablution.† Here, as in so many other cases, we find that the question of origin *de novo*, however important, need not be mixed up with that of the necessary preventive measures. What is important for us is to know—*first*, that it is contagious, that is, transmissible; and, *secondly*, that if not produced, its transmissibility is singularly aided by bad barrack accommodation.

The measures to be adopted if military ophthalmia prevails—

1. *Good Ventilation and Purity of the Air.*—In the Hanoverian army, Stromeyer reduced the number of cases in an extraordinary degree, simply by good ventilation. The only explanation of this must be that the dried particles of pus and epithelium, instead of accumulating in the room, were

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* Ophthalmoscopes are now issued to the different stations, and an Ophthalmoscopic Manual has been drawn up by Mr Longmore for the use of army medical officers. As giving a good survey of military ophthalmia in the British army, the excellent papers of Dr Frank (Army Medical Report for 1860), and Dr Marston (Beale's Archives), should be also referred to. A very interesting paper has also been published by Mr Welch, 22d regiment (Army Medical Report, vol. v. p. 494, 1865), on the "Causes aiding the Development of Granulations at Malta." A warm, moist, impure atmosphere is shown to have a great influence.

† See Dr Frank's papers (Army Medical Report for 1860, p. 406) for some remarks on its spontaneous origin.

carried away, and did not lodge on the eyelids of the healthy men. The evolution of ammonia from decomposing urine has been also assigned as a cause.

It would appear likely that bad barrack air predisposes to granular conjunctivitis by producing some peculiar state of the palpebral conjunctiva and glands (Stromeyer and Frank), and if a diseased person then introduces the specific disease, it spreads with great rapidity, or possibly, as Mr Welch's facts seem to show, the impure atmosphere is the great cause, and contagion only secondary.

2. *Careful Ablution Arrangements.*—An insufficient supply of water for cleansing basins, and the use of the same towels, are great means of spreading the disease, if it has been introduced. Whenever men use the same basins, they should be taught to thoroughly cleanse them, and it would be well if, in every military ablution room, the men were taught not only to allow the dirty water to run away, but to refill the basin with water, which the next comer would let off before filling with fresh water for himself. If some mechanism could be devised for this, it would be very useful. The same towel is a most common cause of propagation; or a diseased man using always the same towel may reinoculate himself. The towels should be very frequently washed (probably every day), and should be dried in the open air, never in the ablution room or barrack.

In some cases special ablution arrangements may cause a good deal of granular conjunctivitis. In 1842 and 1843 I witnessed, in a regiment newly landed in India from England, a very great number of cases of this kind; the supply of water was very insufficient, many men used the same basins, which were very imperfectly cleaned; the same basins were used for washing, and also for dyeing clothes; at that time the men in the cold months wore trousers of a black drill, and when the dye came off they were accustomed to rudely replace it; they themselves ascribed the very prevalent ophthalmia to the irritating effect of the particles of the dye left in the basins, and getting into the eyes. There were enormous granulations on both upper and lower lids, and the disease was believed to be communicable, but whether the affection was strictly to be classed with the vesicular granulations I do not know.

3. In some cases the use of the bedding (pillows and pillow-cases), which has been used by men with grey granulations, has given the disease to others, and this has especially occurred on board transports. In time of war especially this should be looked to. If any cases of ophthalmia have occurred on board ship, all the pillows and mattresses should be washed, fumigated, and thoroughly aired and beaten. The transference has been in this case direct, particles of pus, &c., adhering to the pillow and mattresses, and then getting into the eyes of the next comers.

4. Immediately the disease presents itself, the men should be completely isolated, and allowed to have no communication with their comrades. It has been a great question whether a Government is justified in sending soldiers home to their friends, as it has been thus carried into previously healthy villages. It would seem clear that the State must bear its own burdens, and provide means of isolation, and not throw the risk on the friends and neighbours of the soldier.

An important matter to remember in connection with grey granulations, is, that relapses are very frequent: a man once affected has no safety (Warlomont); simple causes of catarrh and inflammation may then reinduce the specific grey granulations with their contagious characters; so that a man who has once had the disease is a source of danger, and should be watched.

Venereal Diseases.

It is convenient for our purpose to put together all diseases arising from impure sexual intercourse, whether it be a simple excoriation which has been inoculated with the natural vaginal mucus or with leucorrhœal discharges, and which may produce some inguinal swelling, and may either get well in a few days or last for several days; or whether it be an inflammation of the urethra produced by specific (or non-specific? leucorrhœal?) discharge; or whether it be one of the forms of syphilis now diagnosed as being in all probability separate and special diseases, having particular courses and terminations.*

In the army men enter the hospital from all these causes, and from the remoter effects of gonorrhœa or syphilis, orchitis, gleet, stricture, bladder and kidney affection; or syphilitic diseases of the skin, bones, eyes, and internal organs.

The gross amount of inefficiency is tolerably well known (see chapter on Home Service), but it will require a few more years before the several items of the gross amount are properly made out. This arises partly from an occasional great difficulty in the diagnosis of true infecting syphilis, and partly from a want of uniformity in nomenclature.

The comparative amount of army and civil venereal diseases is not known, because we have no statistics of the civil amount. It is no doubt great. It is a question whether a large majority of the young men of the upper and middle classes do not suffer in youth from some form of venereal diseases. In the lower classes it is perhaps equally common.

The sequences are most serious; neglected gleet, stricture, secondary and tertiary syphilis, are sad prices to pay for an unlawful (in some cases a momentary) gratification; and in the army the State yearly suffers a large pecuniary loss from inefficiency and early invaliding. In campaigns the inefficiency from this cause has sometimes been great enough to alarm the generals in command, and to increase considerably the labour and sufferings of the men who are not affected.

1. *Continence.*—The sexual passion in most men is very strong. Providence has, indeed, made it strong enough to lead men to defy all dangers, and to risk all consequences. It has been supposed by some that, in early manhood, continence is impossible, or if practised, is so at the risk of other habits being formed, which are more hurtful than sexual intercourse, with all its danger. But this is surely an exaggeration; the development of this passion can be accelerated or delayed, excited or lowered, by various measures, and continence becomes not only possible, but easy.

For delaying the advent of sexual puberty and desire, two plans, in addition to the restraints of religious duty, can be suggested—absence from exciting thoughts and temptation, and the systematic employment of muscular and mental exercise. The minds of the young are often but too soon awakened to such matters, and obscene companions or books have lighted up in many a youthful breast that *feu-d'enfer* which is more dangerous to many a man than the sharpest fire of the battle-field would be. Among young soldiers this is especially the case; while, in spite of the exciting literature of the day, and of the looseness of some of the older boys at the public schools, or at the univer-

* The singular attempt to argue there is no true syphilitic poison causing a certain and regular series or evolution of diseases is hardly likely to introduce any permanent confusion into this subject. What should have been done, should have been, not to deny the existence of syphilis, but to show what is the precise diagnosis—to do, in fact, for the venereal diseases what has been done for fevers.

sities, the moral tone of the young gentlemen of our day is perhaps better than it was some half century ago, the conversation of the classes from which the soldier is drawn is still coarse and lewd as in the middle ages. There is too close a mixture of the sexes in the English cottages for much decency, and the young recruit does not often require the tone of the barrack to destroy his modesty. In fact, it is possible that, in good regiments, he will find a higher moral tone than in the factory or the harvest field.

We must trust to a higher cultivation, and especially to religious influences, to introduce among the male youth of this nation, in all its grades, a purer moral tone, so that the safeguard of modesty and religious scruples may be cultivated, and not destroyed. In the army, the example of the officers, and their exertions in this way, would do great things, if we could hope that the high moral tone which happily exists in some cases could inspire all.

If exciting and lewd conversation and thoughts should be discouraged by moral and religious teaching, it is not the less necessary to save the young from temptation. The youth of this nation are now sorely tempted. In our streets, prostitution is at every corner, and the most degraded and dangerous strumpets are allowed to congregate round our barracks without hindrance. Whatever may be the objection to police regulations, we have surely a right to demand that the present system of temptation shall be altered. It may not be easy to exclude all prostitutes, especially of the better class (whose calling is less easily brought home to them), from public thoroughfares, but, practically, open prostitution can be recognised and made to disappear from our streets. It has been said our police regulations are sufficient for this; they have never yet proved so; and in no European country but England is prostitution so open and so undisguised.*

Although in our camps and garrisons means could easily be adopted to prevent soldiers being solicited by women, even in the Acts passed in 1864† and in 1866 (Acts of the greatest importance, as the first steps in an efficient legislation), no authority has been taken to prevent prostitutes from assembling in public places near barracks, or to ensure that the public-houses which the soldier frequents are not either brothels or connected with them. To do so would, according to some, be "an interference with the liberty of the subject," as if the State does not, in numberless ways, and most properly, interfere with the liberty of the subject at every turn. It is quite time that this meaningless phrase should disappear, and that men should see that, in the case of venereal diseases, the State must as much protect its citizens, as from the danger of foul water, or the chance of gunpowder explosions, or the risks of any other perilous and unhealthy trade. If men want prostitutes, they must go and seek them. If a woman desires to become a prostitute, she must know that she will not be allowed to pursue her calling in the public streets or in public places, or in houses where men resort for other purposes. In all our garrison towns and camps the public-houses are brothels, and women are under engagements to spend a number of hours there, even if they do not live in them.

If young men could thus escape an appeal to their passions, continence would be much more easy. There are times when the strictest virtue may

* The effect of this upon the virtuous female population is very serious. Every servant in London sees the fine clothes and hears of the idle and luxurious lives of the women of the town, and knows that occasionally respectable marriage ends a life of vice. What a temptation to abandon the hard work and the drudgery of service for such a career, of which she sees only the bright side! It is a temptation from which the State should save her. She should see prostitution as a degraded calling only, with its restrictions and its inconveniences.

† An Act for the Prevention of Contagious Diseases at certain Naval and Military Stations.—1864. An Act for the better Prevention, &c., 1866 (cited as Contagious Diseases Act, 1866).

well dread such an appeal. Human nature is but too weak, and needs every safeguard it can get.

As aids to continence, great physical and mental exertion are most powerful. It would seem that, during great exercise, the nervous energy is expended in that way, and erotic thoughts and propensities are less prominent; so also with mental exercise, in perhaps a less degree. The establishment of athletic sports, gymnasia, and comfortable reading-rooms in the army, may be expected to have some influence.

Temperance is a great aid to continence. In the army, the intemperate men give the greatest number of cases of syphilis; and when a man gets an attack, it is not infrequently found that he was drunk at the time.

The measures which promote continence are then—

(*a.*) The cultivation of a religious feeling, and of pure thought and conversation among the young soldiers, by every means in our power.

(*b.*) Removing from him temptation and occasions to sin.

(*c.*) Constant and agreeable employment, bodily and mentally; as idleness is one great cause of debauchery.

(*d.*) Temperance.

2. *Marriage.*—It is very doubtful whether those who condemn early marriages among the working classes, on account of improvidence, are right in their argument. Probably the early marriages are the salvation of the youth of this country; and in the present condition of the labour market, the best thing a working-man can do is, as early as possible, to make his home, and to secure himself both from the temptations and expenses of bachelorhood. In the case of the soldier there is, for every private under seven years' service, and after seven years' service, for 93 privates out of every 100, a condition of enforced celibacy. It seems difficult to avoid this, with the present conditions of service; and yet, what is the inevitable consequence of shutting out from the prospect or possibility of marriage young men of the soldier's age and education? It should be a matter of grave consideration for the State which places men in such a position. In most of the other armies of Europe the soldier serves for a limited time—three to five years—and can look forward to a speedy release, and to marriage if he pleases. In our service his least period is twelve years. The present system of rapid relief also renders marriage less attractive to the soldier than it was, on account of the great expense the removes put him to. Formerly, when he remained several years, or his whole service, in one station, or at neighbouring stations, his expenses as a married man were light; now, he seldom stops more than three years at any one place.

All that the State can do, is to allow as many men to marry as possible, and to make marriage a reward, by providing good quarters, and by allowances to married men when *en route*. Beyond this it seems impossible to look to marriage as a preventive of venereal disease in the army.

3. *Precautions against the Disease.*—Admitting that, in the case of a body of unmarried men, a certain amount of prostitution will go on,* something

* While saying this, and while dealing with what actually exists, I do not, for a moment, share the opinions of those who look on prostitution not only as a necessity, but as a good—as a shield against worse vices, and as a guard against attempts on married virtue. One feels instinctively that such arguments, however plausible at first sight, are untrue. In fact, they do not bear investigation. Develop the case to a general rule (as Paley advised to be done in all arguments), and its fallacy is manifest. The more prostitution is extended, the more encroachment does it make on marriage—the safeguard of the human race. In its smallest degree it does this. If extended, prostitution would begin to shake the very structure of society—the relations of the sexes, the improvement of both men and women, and the care and culture of the offspring, would become endangered. The more it is considered, the more clearly will the terrible consequences of an extended prostitution come out. But apart from this general view, the

may be done to prevent disease by extreme cleanliness, instant ablution, and by the use of zinc, alum, and iron washes, or similar lotions after connection, and by the constant use by prostitutes of similar washes. It may seem an offence against morality to speak of such things; but we must deal with things as they are; and our object now is not to enforce morality, but to prevent disease. The use in brothels of these measures appears to be more efficacious than any other plan. In some of the French towns the use of lotions and washing is rigorously enforced, with the effect of lessening disease considerably.

4. *Detection and Cure of Diseased Men and Women.*—In the case of the soldier who has medical advice at hand, it seems of the greatest importance to have instant medical aid at the first sign of disease. But, instead of this, the soldier conceals his ailment as long as possible, because he will be sent to hospital, put under stoppages, &c. This is a very bad result of our present system, and the sooner it is altered the better. The soldier should be encouraged to make immediate application, and he should certainly not be punished for a fault which his superiors commit with impunity, and for which the State is in part answerable by enforcing celibacy. Our object is to preserve the man's health and services for the State; we shall not accomplish this by ignoring what is a common consequence of his conditions of service.

Health inspections should be made weekly by the surgeon or assistant-surgeon. I believe these inspections, when carefully made, to be of the greatest service. Some medical officers consider them derogatory, and slur them over. I can neither participate in, nor indeed understand, a feeling of this kind; it seems to me a matter of duty, which should be done as conscientiously as possible. I know from personal experience of health inspections how many men are caught in an early stage of syphilis and gonorrhœa, and the disease is forthwith cured, or greatly mitigated. The more thoroughly these health inspections are again made the better.

It has been also proposed to detect and cure the disease in prostitutes. A great outcry has been raised against this proposal, which is yet a matter of precaution which the State is surely bound to take. A woman chooses to follow a dangerous trade—as dangerous as if she stood at the corner of a street exploding gunpowder. By practising this trade she ought at once to bring herself under the law, and the State must take what precautions it can to prevent her doing mischief. The State cannot prevent prostitution. We shall see no return to the stern old Scandinavian law which punished the prostitute with stripes and death; but it is no more interference with the liberty of the subject to prevent a woman from propagating syphilis, than it would be to prevent her propagating smallpox.

The difficulty is to detect when she is diseased. Abroad, an elaborate system is in use for this purpose;* brothels are registered, and their inmates

effect on the individual man is disastrous, even if he escape venereal disease. Association with a single woman is a safeguard against excess; but if the appetite is stimulated by constant variety, it is impossible to avoid excess, and its enfeebling effects on the body. It is worse than polygamy, as sexual intercourse with different females is more varied. In polygamy, also, it is well known that our common notions of a great number of wives is erroneous; a stop is put by the expense; and in the polygamous nations the majority of men have only one wife. Whenever station or riches enable a man to have more, he pays for his gratification by an enfeebled health, and by a degenerate offspring.

It is not without physiological cause that Christianity has forbidden prostitution, in terms which make us understand, even better than the writings of Terence or Juvenal, how wide-spread and deadly was the prostitution of antiquity, and how the strength and wellbeing of men were being undermined. Is there no danger that we may require similar warnings?

* For an account of the various plans, which have not, I believe, been much altered since that time, I beg to refer to Dr Holland's two articles on Prostitution, in the "British and

regularly examined. In this country such a system seems to many people too like a recognition of the inevitableness of prostitution, and to a certain extent a sanction of it. It does not present itself to me in this light, but as a simple matter of precaution. A custom exists which we cannot set aside; let us obviate its effects as best we may, while, at the same time, by higher culture and better religious teaching, we endeavour to gradually remove the custom.*

A partial adoption of this plan has been commenced by the military and naval authorities in this country, and two Acts have been passed (1864 and 1866), by means of which the prostitutes of certain military and naval stations are brought under supervision.† The important clause in the Act of 1866, is clause 15, which provides that when an information is made on oath that a woman is a common prostitute, living within the limits of any place to which the Act applies, or having been within those limits for the purpose of prostitution, a justice may issue notice to such woman, through the superintendent of police, to appear for medical examination. She is then kept under continued inspection, and certified Lock Hospitals are provided for her treatment if she is discovered to be ill. Clause 36 is also an important one; it imposes a penalty of L.20, or imprisonment, with or without hard labour, on any brothel-keeper or owner of a house who, having reasonable cause to know a woman to be a prostitute, and to be affected with a contagious disease, allows her to resort to the house for the purpose of prostitution.

This Act came into force on the 1st October 1866; and in some stations, as Aldershot it was really more than half a year after this time before it could be put into force.

It is yet too soon to judge of its results, and if I proceed to cite some figures it is only because it is right to see if any progress has yet been made, and whether any obvious imperfections exist in the procedure of the Act.

For the purpose of observing whether the Act has made any difference in the admissions from primary syphilis (using this term in its common acceptation as including all primary venereal sores) and gonorrhœa, I obtained the Director-General's leave to ask for information from some of the principal military stations. The following table gives the results.‡

Foreign Medico-Chirurgical Review" for 1854, and Mr Acton's work, and the recent work by Jeannel, "De la Prostitution dans les grandes Villes," Paris, 1868.

* Those persons who shut their eyes to the enormous prostitution of this country, as of all others, or think nothing can be done because it is impossible to deal with private or "sly" prostitution, and with the higher grades of the calling, should remember that some movement in the interest of the unhappy girls themselves is necessary. In the low brothels in London the system is a most cruel one. A girl is at first well treated, and encouraged to fall into debt to her employer. As soon as she is fairly involved, she is a slave; there is no relief till she can make no more money, when she is cast out. Surely something should be done to save her. Possibly it might be well to try the plan of recognising no debts from a girl to the procuress or brothel-keeper, and to also devise means for at once giving her the means of release from her life if she desires it. Also, if such houses must exist—and who can venture to hope they will not?—they may at least be made less indecent, quieter, and safer from theft, and even murder. At present, the system, as it exists, is a gigantic scandal to Christianity, and Jeannel's singular work has lately shown how curious a parallel there is between modern prostitution and that which dimmed the splendour, and perhaps hastened the fall, of Imperial and Pagan Rome. Eighteen centuries after the death of Christ, are we still at such a point?

† The military stations named in the Contagious Diseases Act of 1866, are Portsmouth, Plymouth, and Devonport; Woolwich, Chatham, and Sheerness; Aldershot, Windsor, Colchester, Shorncliffe, Curragh, Cork, and Queenstown. Adjoining parishes are in many cases included.

‡ My best thanks are due to Inspector-General Dr Lawson, and Deputy-Inspectors Dr C. Gordon, C.B., Dr Inglis, C.B., Dr Bowen, and Dr Ferris, for their kindness in taking much trouble to supply me with information on the working of the Act. In examining into the working of the Act, I have not taken the total admissions of the "enthetic class," as that would be misleading.

	1867. First Quarter	1867. Second Quarter	1867. Third Quarter	1867. Fourth Quarter	1867. Year.	1868. First Quarter	1868. Second Quarter	1868. Third Quarter	1868. Fourth Quarter	1868. Year
Aldershot.										
Mean strength, .	7352	8031	10946	8111	8610	7323	9563	13404	9345	9909
Admissions from primary syphilis,	139	152	204	142	637	147	160	230	218	755
Admissions from gonorrhœa, .	158	204	279	142	783	171	248	313	229	570
Chatham.										
Mean strength, .	3629	3486	3472	3776	3591	3855	3160	3485	3629	3532
Admissions from primary syphilis,	68	61	79	41	249	50	61	63	49	223
Admissions from gonorrhœa, .	108	96	141	147	492	172	142	163	116	593
Plymouth and Devonport.										
Mean strength, .	2212	2217	2616	2713	2439	2395	2605	2290	2256	2386
Admissions from primary syphilis,	34	27	46	75	182	28	37	44	32	141
Admissions from gonorrhœa, .	57	74	169	135	435	96	99	104	54	353
Portsmouth.										
Mean strength, .	4301	3806	3879	4275	4065	4183	4029	4282	4946	4360
Admissions from primary syphilis,	101	99	130	131	461	87	69	112	99	367
Admissions from gonorrhœa, .	182	139	224	222	767	267	245	309	268	1089
Woolwich.										
Mean strength, .	3789	4215	4673	4539	4392*	4220	4551	4082	4170	4255*
Admissions from primary syphilis,	99	96	123	99	411*	36	52	49	59	205*
Admissions from gonorrhœa, .	90	104	184	165	542*	101	145	112	78	439*

Reducing these numbers to ratios per 1000 of strength, we have the following table :—

Admissions per 1000 of Strength.

	1867. Primary Syphilis.	1867. Gonorrhœa.	1868. Primary Syphilis.	1868. Gonorrhœa.
Aldershot, ...	73·98	90·94	76·19	57·50
Chatham, ...	69·34	137·00	62·14	167·89
Plymouth and Devonport, ...	74·62	178·3	59·09	147·9
Portsmouth, . . .	113·40	188·68	84·17	249
Woolwich, . . .	93·57	123·4	48·18	103·17

In 1868, in which year the Act was in full operation, there appears to have

* From 1st January to 31st December.

been a decided decrease of primary syphilis at Plymouth, Portsmouth,* and Woolwich, an inconsiderable decline at Chatham, and an as inconsiderable increase at Aldershot. Taking all the stations, the mean admissions for syphilis were, in 1867, 84·98 per 1000, and in 1868, 65·95 per 1000. It seems, therefore, clear that a good effect has been produced, and I think in the stations where it would have been anticipated. Chatham as the depôt of young soldiers, Aldershot as the place of greatest movement, are the two stations where it might have been expected the Act would be least operative. At Windsor the statements of Dr Wyatt and Dr Myers ("Lancet," 1869) seem to show also a decided effect.

If we take the previous years the evidence is also to the same effect. It may seem singular that even at Aldershot the effect of the Act should not have been more obvious, since many women have been stopped from spreading contagion. At that station the Act of 1866 came into operation on the 1st April 1867; from that date to 31st December 1868, 1186 prostitutes were treated in the hospital there or in London. The effect of this, however, is imperceptible in the Returns. On the 31st December 1868, 5073 women were under the operation of the Act at the various stations. Gonorrhœa appears to have been little affected at present, owing no doubt to the fact that there is not sufficient hospital accommodation for gonorrhœa cases.

The Act at these large stations has done great good in some other directions (especially as regards the women); but as framed and administered, it is far too feebly drawn, and too partially carried out, to cope entirely with the evil. The prostitutes are not thoroughly under inspection; many are not inspected at all; neighbouring towns send in prostitutes; hospital accommodation is insufficient; and there have been too many authorities concerned in the matter.

The prostitutes from surrounding districts not in the Act also come into these towns and camps, either remaining for a few days and then disappearing, or, if diseased, stopping till they can get admitted into hospital. Regiments coming from other quarters not under the Act; men coming from furlough or detachment, also introduce the disease; in fact, the means of evasion and of re-introduction are numerous. Still the results are sufficiently encouraging to make us believe that under a more stringent system a decided influence will be produced.

It is understood that the Government are about to place the whole working of the Act under the Home Office (which will do away with the evil of divided authority), and that a permissive power is to be given to municipalities of all towns to put the Act in force. But it is clear that the evil is too great to be dealt with by piecemeal; it is inevitable but that the Act must eventually be made compulsory over the whole country, and the entire system of prostitution dealt with carefully and completely once for all. It is mere waste of time to allow a permissive bill; it may be a step in the proper direction, but it is postponing the true remedy, and leaving this great evil to sap, for an indefinite time, the health and morals of thousands of persons.

One consequence of the Contagious Diseases Act has been to make public the most frightful state of things among the women of our garrison towns. The vivid picture of the Chatham prostitute's life, drawn by Mr Berkeley

* In the sailors and royal marines at Portsmouth, Dr Gordon informs me that no decided influence is traceable; the millesimial ratio is for both primary syphilis and gonorrhœa—in 1867, for the sailors 246, and for the royal marines, 84·6; in 1868, for the sailors 160, and for the marines 246. At Plymouth, however, there has been a decided lessening among the sailors; the admissions from primary syphilis were, in 1865, 1866, 1867, and 1868 as follows:—321, 249, 185, 156.

Hill,* is no exaggeration. Reports from the Lock hospitals at other places would, if published, bear out all Mr Hill alleges. Shocking as these disclosures are, and mortifying as they may be to our national pride, it is by far the best plan to have them made. An evil like this must not be treated in the shade; it will never be overcome till the public know its proportions; the deadly mists which cling round and poison the very basis of society can be dispersed only when the healing light of the sun falls on them. It is at any rate encouraging to learn that the effect of the Act has already been greatly to improve the manners and habits of the women—to impose some restraint on them, and to restore to them something that, in comparison with their former life, may be called decency. I have been allowed to see a very able report from Dr Barr, which gives a vivid picture of the system at Aldershot, and of the evidently good influence of the Act on the women.†

* British Medical Journal, 1867.

† Since the above was in type, Dr Balfour has been good enough to give me statistics for five years of "venereal sores" and of gonorrhœa for all the army stations at home. I give below the numbers for the five stations noted in the text, and of four others not under the Act, which I selected for comparison for these reasons—Dublin and Edinburgh as two large garrisons; Manchester, as showing the effect of a large manufacturing town; and Winchester, as giving the results in a small garrison, and in a non-manufacturing town. Winchester also being near to Portsmouth, and evidently under better conditions as to venereal than that great sea-port (the operation of the Act being put out of the question), it seemed to me likely to give a good test of the operation of the Act at Portsmouth. I have not included gonorrhœa, as it appears from the tables in the text that gonorrhœa has not been affected by the Act, simply because there has not been hospital accommodation enough to allow gonorrhœal cases to be admitted.

ADMISSIONS FROM "VENEREAL SORES," PER 1000 OF STRENGTH.

In Stations where the Act has been Enforced.

Stations.	1864.	1865.	1866.	1867.	1868.
Aldershot, ...	105·51	100·28	80·55	80·82	76·93
Chatham and Sheerness,	87·8	85·96	83·68	70·74	63·26
Portsmouth, ...	121·28	112·97	100·22	115·83	85·63
Plymouth and Davenport,	150·74	133·12	81·768	75·72	65·75
Woolwich, ...	79·60	75·70	88·99	88·26	46·57

In Stations where the Act has not been Enforced.

Stations.	1864.	1865.	1866.	1867.	1868.
Edinburgh, ...	65·60	112·34	57·60	63·48	45·62
Dublin, ...	179·71	149·87	125·73	129·35	138·83
Manchester, ...	103·95	126·59	92·25	177·27	115·58
Winchester, ...	111·28	72·59	46·33	52·16	104·31

A decision as to the effect of the Act is rendered difficult by the great changes in the number attacked at the same places in different years. Thus at Winchester the variation has been from 46·33 to 111·28, and at Edinburgh from 63·48 to 112·34. The movement of troops, the entry of fresh regiments, and other circumstances, such as increase of pay, all influence the rate. But there is one remarkable point in the table. In the protected stations, the number attacked in 1868 is not only below the mean in the previous four years in every station, but is in every case lower than the minimum of any former year; whereas in two out of the four non-protected stations, the number of attacks in 1868 is above the mean of the previous four years; in one station is only just below, and in only one station is lower in 1868 than in any of the four preceding years.

The mean number of attacks in the five protected stations in 1864 was 108·98, and in 1868 was 67·63. In the four unprotected stations the corresponding numbers were 115·13 and 101·08. And these stations were not selected with a view to getting high or low figures, but simply because they seemed best adapted to test the point. The comparison of Winchester is particularly striking; *à priori*, we should certainly suppose that Portsmouth would give far more venereal than Winchester. It in fact formerly did so, but in 1868 the Portsmouth admissions from venereal sores were 20 per 1000 of strength less.

On the whole, considering how imperfectly, and for how short a time the Act has been applied, I think there is every reason to hope that the lessening of syphilis at all the protected stations in 1868 (though it is inconsiderable in the case of Aldershot), is really owing to the influence of the Act. Three or four years must elapse, however, before the point is quite certain; but at any rate, the above facts should greatly encourage us, and should lead to increased exertions in carrying out the Act.

CHAPTER XIX.

DISPOSAL OF THE DEAD.

In densely populated countries the disposal of the dead is always a question of difficulty. If the dead are buried, so great at last is the accumulation of bodies that the whole country round a great city becomes gradually a vast cemetery.* In some soils the decomposition of bodies is very slow, and it is many years before the risk of impurities passing into air and water is removed.

After death the buried body returns to its elements, and gradually, and often by the means of other forms of life which prey on it, a large amount of it forms carbonic acid, ammonia, sulphuretted and carburetted hydrogen, nitrous and nitric acids, and various more complex gaseous products, many of which are very fœtid, but which, however, are eventually all oxidised into the simpler combinations. The non-volatile substances, the salts, become constituents of the soil, pass into plants, or are carried away in the water percolating through the ground. The hardest parts, the bones, remain in some soils for many centuries, and even for long periods retain a portion of their animal constituents.

If, instead of being buried, the body is burned, the same process occurs more rapidly and with different combinations; carbonic acid, carbonic oxide (?) nitrogen, or perhaps combinations of nitrogen, water, &c., are given off, and the mineral constituents, and a little carbon, remain behind.

A community must always dispose of its dead either by burial in land or water, or by burning, or chemical destruction equivalent to burning, or by embalming and preserving. Accustomed as we are to land burial, there is something almost revolting, at first sight, at the idea of making the sea the sepulchre, or of burning the dead. Yet the eventual dispersion of our frames is the same in all cases; and it is probably a matter merely of custom which makes us think that there is a want of affection, or of care, if the bodies of the dead are not suffered to repose in the earth that bore them. If we read the Bible aright—that our bodies are to rise again—it must be by a miracle, which, in some way incomprehensible to us, will bind up again the scattered elements, and from the four winds of heaven call the dispersed atoms to the promised land.

In reality, neither affection nor religion can be outraged by any manner of

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* Nothing, perhaps, testifies more strongly to the antiquity and the extent of the ancient cities in Anatolia than the vast sepulchral remains. On the site of old Dardanus, the mother of Troy, and stretching from the Hellespont for two or three miles into the hills, the whole country is honeycombed with tombs. It is the same in the neighbourhood of Troy. The burial of the dead, though practised by the most ancient nations, was afterwards superseded by burning, and was only subsequently returned to. As, therefore, these graves represent only a portion of the duration of the city, the immense assemblage of tombs is the more remarkable, and it is impossible to avoid the conclusion that these great cities must have flourished for periods far longer than those which have elapsed since London or Paris, for example, became large centres of population.

disposal of the dead which is done with proper solemnity and respect to the earthly dwelling-place of our friends. The question should be placed entirely on sanitary grounds, and we then shall judge it rightly.

What, then, is the best plan of disposing of the dead, so that the living may not suffer?

It seems hardly likely that the practice of embalming or mummifying will ever again become common. What is the use of preserving for a few more years the remains which will be an object of indifference to future generations? The next logical step would be to enshrine these remains in some way so as to ensure their preservation, and we should return to the vast burial mounds of Egypt. The question will lie between burial in the land or at sea, and burning.

At present the question is not an urgent one; but if peace continue, and if the population of Europe increase, it will become so in another century or two. Already in this country we have seen, in our own time, a great change; the objectionable practice of interment under and round churches in towns has been given up, and the population is buried at a distance from their habitations. For the present that measure will probably suffice, but in a few years the question will again inevitably present itself.

Burying in the ground appears certainly the most insanitary plan of the three methods. The air over cemeteries is constantly contaminated, and water (which may be used for drinking) is often highly impure. Hence, in the vicinity of graveyards two dangers to the population arise, and in addition, from time to time, the disturbance of an old graveyard has given rise to disease. It is a matter of notoriety that the vicinity of graveyards is unhealthy. How are these dangers to be avoided? The dead may be buried in more or less air-tight vaults; here decay is slow; the products form and escape slowly, though they must eventually escape; and air and water are less contaminated. But the immense expense of such a plan renders it impossible to adopt it for the community generally. Deep burying has the advantage of greater filtration, both for air and water, than shallow burying, and hence it is a good rule to make the grave as deep as possible, and to allow no more than one body in a grave. The admixture of quicklime has been advised; it absorbs some carbonic acid, and forms sulphuret of calcium with the sulphur and sulphuretted hydrogen, but this itself soon decomposes, so that the expense of quicklime seems hardly commensurate with the result. Charcoal would absorb and oxidise the fœtid organic matter, and, if sufficiently cheap, would be a valuable substance to be heaped in graves; but its cost would be probably too great, nor does it entirely hinder putrefaction and the evolution of foul-smelling substances (H. Barker). If a body has to be kept unburied for some time, sawdust and sulphate of zinc, in the proportion of two parts to one, has been found by Herbert Barker* to be the best existing; a thin layer is put over the dead body; or sawdust is sprinkled on the body, and then two or three ounces of carbolic acid thrown over it.

The only means which present themselves, as applicable in all cases, are the deep burial and the use of plants, closely placed in the cemetery. There is no plan which is more efficacious for the absorption of the organic substances, and perhaps of the carbonic acid, than plants, but it would seem a mistake to use only the dark, slow-going evergreens. The object should be to get the most rapidly growing trees and shrubs, and, in fact, there is no reason, except a feeling of sentiment, why we should introduce into our cemeteries the gloomy and melancholy cypress and yew.

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* Deodorisation and Disinfection, "British Medical Journal," January 1866.

When, in the course of years, it becomes imperative to reconsider this question, and land burial will have to be modified, many arguments will present themselves to maritime nations in favour of burying in the sea rather than of burning. It is true that the impurities in burning can be well diffused into the atmosphere at large, and would not add to it any perceptible impurity. But if the burning is not complete, fœtid organic matters are given off, which hang cloud-like in the air, and may be perceptible, and even hurtful. As a matter of expense, too, the system of incremation would be greater than the burial at sea. In the burial at sea, some of the body would go at once to support other forms of life, more rapidly than in the case of land burial, and without the danger of evolution of hurtful products; and in the vast abyss of the ocean the remains would rest until the trumpet shall sound which shall order the sea to give up its dead.

In time of war, and especially in the case of beleagured fortresses, the disposal of the dead becomes often a matter of difficulty. In that case burning may have to be resorted to. If the bodies are buried, they should always be at as great a distance as possible, and as deep as they can be. If procurable, charcoal should be thrown over them; if it cannot be obtained, sawdust and sulphate of zinc, or carbolic acid may be employed. Quicklime is also commonly used, but is less useful.

CHAPTER XX.

INDIVIDUAL HYGIENIC MANAGEMENT.

This subject is an extremely large one, and the object of this book does not allow me to discuss it. It would require a volume to itself. I can merely here make a few very general remarks. The application of general hygienic rules to a particular case constitutes individual management.

It is impossible to make general rules sufficiently elastic, and yet precise enough, to meet every possible case. It is sufficient if they contain principles and precepts which can be applied. While individual hygiene should be a matter of study to all of us, it is by no means desirable to pay a constant or minute attention to one's own health. Such care will defeat its object. We should only exercise that reasonable care, thought, and prudence which, in a matter of such moment, every one is bound to take.

Every man, for example, who considers the subject *bonâ fide*, is the best judge of the exact diet which suits him. If he understands the general principles of diet, and remembers the Hippocratic rule, that the amount of food and exercise must be balanced, and that evil results from excess of either, he is hardly likely to go wrong.

"Temperance and exercise" was the old rule laid down, even before Hippocrates,* as containing the essence of health; and if we translate temperance by "sufficient food for wants, but not for luxuries," we shall express the present doctrine.

The nutrition of the body is so affected by individual peculiarities, that there is a considerable variety in the kind of food taken by different persons. The old rule seems a good one, viz., while conforming to the general principles of diet, not to encourage too great an attention either to quantity or to quality, but avoiding what experience has shown to be manifestly bad, either generally, or for the particular individual, to allow a considerable variety and change in amount from day to day, according to appetite.† Proper and slow mastication of the food is necessary; and it is extraordinary how many affections of

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* It is quite plain from the context, that Hippocrates, by temperance, meant such an amount of food as would balance, and neither exceed nor fall short of the exercise. He had a clear conception of the development of mechanical force from, and its relation to, food. He lays down rules to show when the diet is in excess of exercise, or the exercise in excess of diet. In either case he traces disease.

† Celsus carried the plan of variety so far as to recommend that men should sometimes eat and drink more than is proper, and should sometimes not exceed; and Lord Bacon has a remark which leads one to believe he held a similar opinion; but there can be no doubt of the incorrectness of this opinion. It has been truly said that the first general rule of Hippocrates, which prescribes continual moderation, is much truer, and the best writers on hygiene, ancient and modern, have decided against Celsus. Besides being erroneous, the rule of Celsus opens a door to intemperance, and, like a harmless sentence in Hippocrates, has been twisted to serve the argument of gourmands. Its influence is felt even at the present day. This much is certain, that probably 30 per cent. of the persons who consult physicians owe their diseases in some way to food, and in many cases they are perfectly aware themselves of their error or bad habit, but, with the singular inconsistency of human nature, either conceal it from the man to whom they are professing perfect openness, or manage to blind themselves to its existence.

the stomach called dyspepsia arise simply from faulty mastication, from deficient teeth, or from swallowing the food too rapidly. Many persons who are too thin are so from their own habits; they eat chiefly meat, and eat it very fast; they should eat slowly, and take more bread and starchy substances. Fat persons, on the other hand, by lessening the amount of starch, and taking more exercise, can lessen with the greatest ease the amount of fat to any amount. It must be remembered, however, that there is a certain individual conformation in this respect; some persons are normally fatter or thinner than others.

The exact amount of exercise must also be a matter of individual decision, it being remembered that great exercise in the free air is a paramount condition of health, and that the healthiest persons are those who have most of it. As a rule, persons take far too little exercise, especially educated women, who are not obliged to work.*

Attention to the skin is another matter of personal hygiene.

The skin must be kept perfectly clean, and well clothed. Some writers, indeed, have advised that, if food be plentiful, few clothes be worn; but the best authors do not agree in this, but recommend the surface to be well protected. For cleanliness, cold bathing and friction hold the first rank. The effect of cold is to improve apparently the nutrition of the skin, so that it afterwards acts more readily, and when combined with friction, it is curious to see how the very colour and texture of the skin manifestly improve.

The effect of heat on the skin, and especially the action of the Roman or Turkish baths, and their action on health, has certainly not yet been properly worked out, in spite of the numerous papers which have been written. It has not been proved that the strong action of the Turkish bath is more healthy in the long run than the application of cold water. As a curative agent, it is no doubt extremely useful; but as a daily custom, it is yet *sub judice*. Certainly it should not be used without the concluding application of cold to the surface.

Attention has been lately very properly directed to the effect of lead and mercurial hair dyes. It may be worth while to notice that there is a case on record† in which not only was paralysis produced by a lead hair-wash, but lead was recovered from the base of the left hemisphere of the brain. Snuff containing lead has also caused poisoning.

The care of the bowels is another matter of personal hygiene, and is a matter of much greater difficulty than at first sight appears. Constipation, as allowing food to remain even to decomposition, as leading to distention and sacculation of the colon, and to hæmorrhoids, is to be avoided. But, on the other hand, the constant use of purgative medicine is destructive of digestion and proper absorption; and the use of clysters, though less hurtful to the stomach, and less objectionable altogether, is by no means desirable. On the whole, it would seem that proper relief of the bowels can be usually ensured by exercise, and especially by bringing the abdominal muscles into play, and by the use of certain articles of diet—viz., pure water in good quantity with meals, the use of bran bread, honey, and such gently laxative food; and that if these do not answer well, it is better to allow a certain amount of constipation than to fall into the frequent use of purgative medicines.

The regulation of the passions must also be left to the individual. In these

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* Compare the imperfect development of the muscles of the arms in ladies, as shown by the low evening dresses, with the women of the working classes. No one can doubt which is healthiest or which is the most beautiful, until excess of work developes in the muscles of the labouring women the too hard outlines of middle life.

† Virchow's Archiv, band viii. p. 177.

days of too early sexual life, no subject is perhaps more important than this one. In how many ways are health and vigour injured by the want of control! To say nothing of the venereal diseases, with all their consequences, how much evil results even from unbridled erotic thoughts and the habits which sometimes follow! But the young often err only from ignorance, and should be taught that perfect health and vigour are only possible when there is perfect sexual health.

Among soldiers the amount of venereal disease is discussed in another chapter. The practice of masturbation is, I believe, in our own army happily uncommon; in other armies a few expressions by authors lead me to think it is less uncommon; but it is a subject which, in spite of its importance, few have cared to look into.

The amount of mental work, and the practice of general good temper and cheerfulness and hope, are other points which each man must himself control. Great mental work can be borne well if hygienic principles of diet, exercise, &c., be attended to. The old authors paid great attention to the regimen of men engrossed in literary work, and laid down particular rules, insisting especially on a very careful and moderate diet, and on exercise.*

Hope and cheerfulness are great aids to health, no doubt, from their effect on digestion. Usually, too, they are combined with a quick and active temperament, and with rapid bodily movements and love of exercise.

The individual application of general hygienic rules will differ according to the sex and age,† and the circumstances of the person. In the case of children, we have to apply the general rules with as much caution and care as possible, and we must depend on external evidence to prove their utility. In the case of adults, individual experience soon shows whether or not a prescribed rule is or is not beneficial, and what modification must be made in it. It is not, however, every grown person who has the power to modify or change his condition. He may be under the influence of others who, in fact, arrange for him the circumstances of his life. But still, in no case is all self-control taken away; the individual can always influence the conditions of his own health. Probably even in the case of soldiers he has more power over his own welfare than other persons have.

Were the laws of health and of physiology better understood, how great would be the effect! Let us hope that matters of such great moment may not always be considered of less importance than the languages of extinct nations, or the unimportant facts of a dead history.

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* Plutarch, whose rules on health are excellent, and chiefly taken from Hippocrates, compares the over-studious man to the camel in the fable, who, refusing to ease the ox in due time of his load, was forced at last to carry not only the ox's own load, but the ox himself, when he died under his burden.

† Galen was the first who pointed out explicitly that hygienic rules must be different for infancy, youth, manhood, and old age—a fourfold division which is still the best. Pythagoras, Iccus, Herodicus, Hippocrates, Polybus, Diocles, Celsus, and others who preceded Galen, appear to have framed rules chiefly for male adults. Galen sub-divided the subject much more systematically. (For a good short account of the early systems, see Mackenzie on "The History of Health, and the Art of Preserving it," 1758.)

CHAPTER XXI.

STATISTICS.

An accurate basis of facts, derived from a sufficient amount of experience, and tabulated with the proper precision, lies at the very foundation of hygiene, as of all exact sciences. Army surgeons have already contributed much important statistical evidence as to the amount and prevalence of different diseases, and it is evident that no other body of medical practitioners possess such opportunities of collecting, with accuracy, facts of this kind, both among their own nations and others. As they have to make many statistical returns, it seems desirable to make a few brief remarks on some elementary points of statistics, which are necessary to secure the requisite accuracy in collecting and arranging facts. But it is, of course, impossible for me to enter into the mathematical consideration of this subject; even were I competent, a separate treatise would be required to do justice to it.

SECTION I.

A FEW ELEMENTARY POINTS CONNECTED WITH GENERAL STATISTICS.

1. The elements of statistical inquiries are individual facts, or so-called numerical units, which having to be put together, or classed, must have precise, definite, and constant characters. For example, if a number of cases of a certain disease are to be assembled in one group with a definite signification, it is indispensable that each of these cases should be what it purports to be, an unit not only of a definite character, but of the same character as the other units. In other words, an accurate diagnosis of the disease is essential, or statistical analysis can only produce error. If the numerical units are not precise and comparable, it is better not to use them. A great responsibility rests on those who send in inaccurate statistical tables of diseases; for it must be remembered that the statist does not attempt to determine if his units are correct; he simply accepts them, and it is only if the results he brings out are different from prior results that he begins to suspect inaccuracy.*

2. These items or numerical units being furnished to the calculator, are by him arranged into groups; that is to say, he contemplates the apparently

* It is in vain to conceal the fact that many persons look at tables of diseases collected indiscriminately as worse than useless, from errors in diagnosis. Even in the army returns, which are all furnished by qualified practitioners, there is reason to doubt the correctness of the earlier tables especially. But it is believed that the army returns of diseases are now gaining in accuracy, and it cannot be too strongly urged on medical officers that perfect accuracy in diagnosis is a duty of the highest kind. It is much better to have a large heading of undetermined diseases than, when in doubt, to put a case of disease under a heading to which it has no unequivocal pretensions.

homogeneous units in another light, by selecting some characteristic which is not common to all of them, and so divides them into groups. To take the most simple case: A certain number of children are born in a year to a given population. The children are the numerical units. They can then be separated into groups by the dividing character of sex, and then into other groups by the dividing character of "born alive," or "still born," &c.

Or, a number of cases of sickness being given, these numerical units (all agreeing in this one point that health is lost) are divided into groups by diseases, &c.; these groups, again, are divided into others by the character of age, &c., and in this way the original large group is analysed, and separated into minor parts.

This group-building seems simple, but to properly group complex facts, so as to analyse them, and to bring out all the possible inferences, can only be done by the most subtle and logical minds. The dividing character must be so definite as to leave no doubt into which group an unit shall fall. This rule is of the greatest importance, and many examples could be pointed out of error from inattention to it. The dividing character must be precise enough to prevent the possibility of an unit being in two groups at the same time.

Having decided on the groups, their numerical relations are then expressed in figures, for example:—

3. In order to express the relation of the smaller groups to the gross number of individual facts or units, a constant numerical standard must be selected, else comparison between groups of unequal numbers cannot be made. The standard universally adopted in medical statistics is to state this relation as a percentage, or some multiple of a percentage. So much per cent., or per 1000, or per 10,000, is the standard. This is got simply by multiplying the number of units in the smaller group by 100, and dividing by the total number of units. Thus, let us say there occur 362 cases of pneumonia; this is divided into two groups of recovered or died, say 343 recoveries and 19 deaths; and their relation may be expressed in one of two ways, viz., either by the relation of the deaths to the total number of cases, which will be—

$$\frac{19 \times 100}{362} = 5{\cdot}248 \text{ per cent.}$$

of mortality; or by the relation of the deaths to recoveries, viz.—

$$\frac{19 \times 100}{343} = 5{\cdot}54 \text{ per cent.}$$

4. Having established that in a certain number of cases, divided into groups, the number in each group bears a certain proportion to the whole, how far are we justified in concluding that the same proportions will be repeated in future cases? This will chiefly depend on the number of the cases. If the number of cases from which one proportion has been taken is small, we can have no confidence that the same proportion will be repeated in future cases. If the number is large, there is a greater probability that the proportion in succeeding numbers of equal magnitude will be the same. The result obtained even from a very large number is, however, only an approximation to the truth, and the degree in which it approaches the truth can be obtained by calculation. The following rule is given by Poisson for calculating the limits of error, or, in other words, the degree of approximation to the truth:—

Let μ be the total number of cases recorded.
m be the number in one group.
n be the number in the other.

So that $m + n = \mu$.

The proportion of each group to the whole will be respectively $\frac{m}{\mu}$ and $\frac{n}{\mu}$, but these proportions will vary within certain limits in succeeding instances. The extent of variation will be within the proportions represented by

$$\frac{m}{\mu} + 2\sqrt{\frac{2 \,.\, m \,.\, n}{\mu^3}}$$

and

$$\frac{m}{\mu} - 2\sqrt{\frac{2 \,.\, m \,.\, n}{\mu^3}}$$

It will be obvious that the larger the value of μ the less will be the value of $\sqrt{\frac{2 \,.\, m \,.\, n}{\mu^3}}$, and consequently the less will be the limits of error in the simple proportion $\frac{m}{\mu}$.

An example will show how this rule is worked. The following is given by Gavarret (Statistique Médicale, 1840, p. 284):—

Louis, in his work on Typhoid Fever, endeavours to determine the effect of remedies, and gives 140 cases, with 52 deaths and 88 recoveries. What is the mortality per cent., and how near is it to the true proportion?

$$m = 52 = \text{number of deaths.}$$
$$n = 88 = \text{number of recoveries.}$$
$$\mu = 140 = \text{total number of cases.}$$

i.e., 37 deaths in 100 cases, or more precisely 37,143 deaths in 100,000 cases. How near is this ratio to the truth? The possible error is as follows—the second half of the formula, viz.—

$$2\sqrt{\frac{2 \,.\, m \,.\, n}{\mu^3}}$$

will be

$$2\sqrt{\frac{2 \times 52 \times 88}{(140)^3}} = 0{\cdot}11550 \text{ to unity.}$$

(Or 11,550 in 100,000.)

The mortality being 37·143 per cent., or 37,143 deaths in 100,000 cases, in these cases, it may be in other 140 cases either

$$37{,}143 + 11{,}550 = 48{\cdot}693 \text{ per cent.,}$$

or

$$37{,}143 - 11{,}550 = 25{\cdot}593 \quad ,,$$

In other words, in successive 140 cases the mortality will range from 49 per cent. (nearly) to 26 per cent. (nearly), so that Louis' numbers are far too few to give even an approximation to the true mean.

5. There being a number of facts, each of which can be expressed by a numerical value, an average or mean number is obtained by adding all the numerical values, and dividing by the number of facts.*

In many cases the method by successive means is very useful. This consists in taking the mean of the mean numbers successively derived from a constantly repeated series of events (say the mortality to a given population yearly). Supposing, for example, the annual mortality in England to be, in

* The arithmetical mean is used in medical inquiries; but there are, in addition, the geometrical, harmonic, and quadratic means. For an account of these, and for many rules, I beg to refer to Dr Bond's translation of Professor Radicke's Essay, New Sydenham Society Publ. vol. xi.

successive years, 22, 23, 21, 26, 23, 21, 22, 28, 22, 21, per 1000 living, the successive means would be—

$$\frac{22 + 23}{2} \qquad \frac{22 + 23 + 21}{3} \qquad \frac{22 + 23 + 21 + 26}{4}$$

and so on, until the numbers are so great as to give every time the same result. It is useful to calculate the successive means in both the direct and inverse order, viz., from first to last, and then from last to first, *i.e.*, putting the two last together, then the three last, &c., so as to see if the variation was greater at the end of a series than at the beginning. The degree of uncertainty is then the mean variation between the successive means.*

A plan almost the same as this has been used; a certain number of facts being recorded, the sum is divided into two, three, or more parts, and it is then seen whether the results drawn from these lesser groups agree with that drawn from the larger group and with each other. If there is any great difference of results, the numbers of the lesser groups are not sufficient. In the instance given above, the mean of the ten years is 22·9; the mean of the first three years is 22; of the second three years is 23·33; of the third three years is 24. The term of three years is therefore far too short to allow a safe conclusion to be drawn. The mean of five years again is 23, and of eight years is 22·8, numbers which are much nearer each other and the mean of the whole ten years.

The application of averages when obtained is of great importance, but there is one usual error. The results obtained from an average (that is, from the mean result obtained from a number of units, not one of which perhaps is the same as the mean result, but either above or below it) can never be applied to a particular case. On either side the average there is always a range the value of which may be obtained by Poisson's rule as above, and the particular case may be at either end of the range. The use of the average is to apply it to an aggregate of facts, then supposing it be founded on a sufficient number of cases, it will be exact. But a particular case can never be judged of by the average.

6. In addition to averages, it is always desirable to note extreme values, that is, the two ends of the scale of which the average is the middle. To use Dr Guy's pointed expression, "averages are numerical expressions of probabilities; extreme values are expressions of possibilities."† In taking too great note of mean quantities, we may forget how great a range there may be above and below them, and it is by reminding us constantly of this that Poisson's rule is so useful.

7. Statistical results are now frequently expressed by graphic representations, a certain space drawn to scale representing a number. The most simple plan is that of intersecting horizontal and vertical lines.

Two lines, one horizontal (axis of the abscissæ), and the other vertical (axis of the ordinates), from two sides of a square, and are then divided into segments, drawn to scale—vertical and horizontal lines are then let fall on the points marked; the axis of the ordinates representing, for example, a certain time, and the axis of the abscissæ representing the number of events occurring at any time. A line drawn through the points of intersection of these two quantities forms a graphic representation of their relation to each other, and the surface thus cut can be also measured and expressed in area if required, or

* The mean error is best obtained by taking the quadratic mean, *i.e.*, the square root of the sum of the square of the errors; but the arithmetical mean error—that is, the sum of the errors divided by the number of means—gives a tolerably close approach.

† Cyclopædia of Anatomy and Physiology—Art. *Statistics*.

the space can be plotted out in various ways, in columns, pyramids, &c. In the same way circles cutting radii at distances from the centre drawn to scale are very useful; the circles marking time (in the example chosen), and the radii events, or the reverse. Such graphic representations are most useful, and allow the mind to seize more easily than by rows of figures the connection between two conditions and events.

Generally speaking, it may be said that the amounts of sickness and mortality in different bodies of men, or in the same body of men at successive periods, show such wide variations that the mean error is always very great, and it requires a very large number of cases, and an extended period, to deduce a probable true mean. For this reason it is necessary to be cautious in apportioning blame or credit to persons, or to special modes of treatment, unless the numbers are very large and accordant. The circumstances influencing the result are, in fact, very numerous, and the proper estimation of a numerical result is only possible when it is considered in reference to the circumstances under which it occurs.

The most important statistical inquiries applied to health are—

1. *Births to Population.*—To obtain all these elementary facts, an accurate census and proper registration are required. It is only within the last few years that the most civilised nations have commenced these inquiries.

2. *Relative Number of Live and Still-Born, of Premature and Full-Grown Children.*

3. *Number of Children Dying in the First Year, with Sub-Groups of Sex, and Months.*—There are two great periods of mortality in the first year, viz., in the first week, and at the time of weaning, about the seventh month.

4. *Amount of Sickness to Population.*
    (*a.*) Number constantly sick, grouped according to sex, age, occupation, and diseases.
    (*b.*) Average duration of sickness, &c.

5. *Amount of Yearly Mortality in a Population, or Deaths to Population.*—The deaths are generally expressed as so many deaths to 1000 or 10,000 living; but the deaths can be calculated in relation not only to the number living at the end of the time, but to that number *plus* a certain addition to be made on account of those persons who lived during part of the time, but died before its close. But the difference is not material. Grouped according to sex, age, &c.

6. *Mean Age at Death of a Population is the Sum of the Ages at Death, divided by the Deaths.*—The mean age at death expresses, of course, the expectation of life at birth, or the mean lifetime. It is no very good test of the health of a people, as a great infant mortality may reduce the age, though the health of the adults may be extremely good. The mean age of death in England is about 40 years.

7. *Mean duration of Life* (*vie moyenne*).—This is the expectation of life at birth; at any other age than birth, it is the expectation of life at that age (as taken from a life table) added to the age. It is no good test of sanitary condition or health.

8. *Probable Duration of Life* (*vie probable;* probable lifetime) is the age at which a given number of children born into the world at the same time will be reduced one-half.

9. *Expectation of Life, or Mean Future or After Lifetime.*—This is the true test of the health of a people. It is the average length of time a person of any age may be expected to live; and in order to construct it, we must know the number of the living, their ages, the number of deaths and the ages, and

the other changes in the population caused by births, emigration, immigration, &c. It does not, of course, follow that any particular person will live the time given in such a table; he may die before or after the period, but taking a large number of cases, the average is then found to apply. Life-tables show at a glance the expectation of life at any age.

*England.**

Age.	Males.	Females.	Age.	Males.	Females.	Age.	Males.	Females.
0	39·91	41·85	10	47·05	47·67	70	8·45	9·02
1	46·65	47·31	20	39·48	40·29	80	4·93	5·26
2	48·83	49·40	30	32·76	33·81	90	2·84	3·01
3	49·61	50·20	40	26·06	27·34	95	2·17	2·29
4	49·81	50·43	50	19·54	20·75	100	1·68	1·76
5	49·71	50·33	60	13·53	14·34			

After the first year the chances of living increase up to the fourth year; the fifth year is nearly as good, and then the chances of life lessen, but at first slowly, and then more rapidly; from 5 to 40 years of age the expectation of life lessens in the ratio of from 2½ to 3½ or 3¾ years for each quinquennial period.

SECTION II.

ARMY STATISTICS.†

At the close of the Peninsular war in 1814, Sir James M'Grigor commenced the collection of the statistics of disease and mortality in the English army, and during the course of the next twenty years a great amount of valuable evidence was accumulated. In 1835 Dr Henry Marshall (Deputy-Inspector of Hospitals, and one of the most philosophical surgeons who have ever served in the English army) commenced to put these returns into shape, and the late Major-General Sir Alexander Tulloch, K.C.B. (at that time a lieutenant in the 45th Regiment, employed in the War Office), was associated with him. In the following year, on the retirement of Dr Marshall, Dr Balfour, the present head of the Statistical Branch of the Army Medical Department, was appointed as his successor, and in conjunction with Sir A. Tulloch, brought out the series of reports on the health of the army which have had such influence, not merely on the causes of the sickness and mortality among soldiers, but indirectly on those of the civil population also. In 1838–1841, reports were issued of the following stations:—United Kingdom, Mediterranean, and British America, West Indies, Western Africa, St Helena, Cape, Mauritius, Ceylon, and Tenasserim.

These returns included the years 1817–1836. In 1853 another report, containing the stations of the troops in the United Kingdom, Mediterranean, and British America, including the years 1836–1846, was prepared by the same gentlemen.

In these reports, in addition to the statistical analysis, short but most graphic and comprehensive topographical and climatic accounts of the different stations were given.

The effect of these several reports, and especially of the earlier issues, was

* Abridged from Dr Farr's Life Tables.

† The short summary of the history of the Army Statistical Reports is chiefly taken from Dr Balfour's account, in the Army Medical Report for 1860, p. 131.

to direct the attention of the Government, both to the fact of an enormous sickness and mortality, and to its causes, and then commenced the gradual series of improvements which at a later period were urged on by Lord Herbert with so much energy.

The Russian war of 1854–1855 prevented any further publication until 1859, when yearly reports were commenced by Dr Balfour, and have been regularly issued since. In the report for 1860, Dr Balfour has given a summary of the earlier and later mortality of the different stations before and after 1837, which shows a remarkable difference in favour of the later periods as regards both sickness and mortality.*

Sub-Section I.

With respect to soldiers *in time of peace*, the statistical evidence is required to show the amount of benefit the State receives from its soldiers, and the amount of loss it suffers yearly from disease. Tables should therefore show—

1. The amount of loss of strength a definite number of men in each arm of the service suffers in a year—

(*a.*) By deaths, or, in other words, the mortality to strength.

(*b.*) By invaliding from disease,† for if this is not regarded, different systems and modes of invaliding may entirely vitiate any conclusions drawn from the mortality.

The groups thus formed must be again subdivided, so as to show—

(*a.*) The causes of death or invaliding.

(*b.*) The ages of those who die or who are invalided.

(*c.*) Their length of service. It is of great importance to determine the influence of service in every year, and these groups should be again divided by ages.

2. The loss of effective service a definite number of men—say, 1000 in each arm—suffers during a year. This is best expressed as fellows :—

(*a.*) The total number of cases of disease in a year, *i.e.*, the number of admissions to hospital per annum. It must be understood that this does not express the number of men admitted, as one man may be admitted two, three, or even ten times with the same disease; each admission counts as a fresh case. It would be very important to have another table showing the number of men admitted for different diseases, or, in other words, the number of cases of re-admission for the same disease.

(*b.*) The number constantly sick on an average. This is often called the sick population, and is obtained most easily in army hospitals by dividing the number of diets issued in a year by the purveyor by 365, or adding all the "remaining" on the daily or weekly states together, and dividing by 365 or 52, as the case may be.

(*c.*) The total number of days lost in a year to the service by illness by the 1000 men, and of the number of days per head. The number of the sick population (that is, the number constantly sick out of, say 1000 men) multiplied by 365 and divided by 1000, or by the number furnishing the sick, whatever that may be, gives these facts.

(*d.*) The mortality in relation to sickness.

The group constituted by the sick must then be subdivided by diseases,

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* In the chapter on India, I have mentioned the chief statistical papers which refer to that country.

† Loss by purchase of discharge, expiration of term of service, imprisonments, and dismissals from the army, must also be put under separate headings; but the medical officer has nothing to do with this point, except to see that such cases are not confounded with invaliding from disease.

and often it is useful to make other lesser groups by distributing the causes of sickness under ages or length of service.

There are a few points which require attention. The amount of sickness and mortality is calculated on the mean strength, that is, the number of men of a regiment present at a certain station on the muster days divided by the number of muster days. But it must be understood that this includes the sick men in hospital as well as the healthy men, and therefore does not perfectly express the amount of disease among the healthy men. Also sometimes the muster rolls of a regiment include men on detachment at some distance, whose sickness is not attributable to the headquarter station. The French, in their Army Statistical Returns, make two headings, one of "mean strength (*effectif moyenne*), and the other of "present" (*présents*), the men in hospital not being included in the latter. Moreover, in the French army, nearly one-sixth are always absent on leave; and the deaths of those on leave are included among the army deaths, but the sickness is not so. Consequently, sickness has to be calculated on the number not on leave; deaths, on the total strength. In the French army, officers are included with the men; in the English, separate returns are made.

It is often difficult to get the mean strength if there are many changes of troops, and instances of erroneous calculations from this cause are not uncommon.*

In calculating also the effect of age and length of service upon disease and mortality, it is necessary to know not only the ages and length of service of the sick men, but of the healthy men also, and to calculate out the proportion of the sick to the healthy at that particular age or length of service, otherwise very erroneous conclusions might be drawn. For example, it might appear that sick men under nineteen years of age were very numerous in proportion to other years, but in a young army the greater number of the force might be of this age. Care is necessary in all these points to arrive at correct conclusions.

Sub-Section II.—Statistics in War.

In time of war the statistics must be slightly altered in form, though the same in principle, The object is to show as completely as possible to the General in command what amount of loss his army is suffering at the moment, and to what extent it may be expected to suffer, and also what are the causes of such sickness.

The sickness here must not only be calculated on the mean strength (which

* I subjoin one which Dr Balfour has given. It will be seen that an unhealthy station (Masulipatam) in India is credited with a much greater degree of health than it really was entitled to, and the annexed extract from Dr Balfour's paper (Edin. Med. and Surg. Jour. No. 172) shows clearly how the mistake arose :—

"The [Madras] Medical Board, in submitting to Government the table from which these figures are computed, stated that the ratio of mortality among all the European regiments in the Presidency from January 1813 to December 1819, was 5·690 per cent. ; while that of the regiments at Masulipatam, from 1813 to 1832 inclusive, was 5·100 per cent. They then add—'The rate of mortality having been somewhat lower than throughout the rest of the Presidency for such a period, gives reason to conclude that the station cannot be considered under ordinary circumstances as unhealthy.' Now, the Board appears to have arrived at this conclusion from an error in the mode of calculating the ratio. In several of the years between 1813 and 1832 the regiments were quartered at Masulipatam during part of the year only. It must be obvious to any one conversant with the principles of statistics, that in such a case a proportion of the annual strength only should be taken, corresponding with the period for which the regiment was quartered there. Thus, if the period was nine months, the sickness and mortality should be calculated on three-fourths of the strength ; if eight months, on two-thirds, and so forth. The Board, however, have made the calculation in every instance on the average annual strength without any such deduction. Had the necessary correction been made, the deaths from 1813 to 1832 would have been found to average 6·391 per cent. annually, instead of 5·100, as above stated."

will include the men in hospital), but also on the healthy men, or those actually under arms and effective. If the sick are counted in the strength, the sickness of the army may be much understated. What a General wants to know with regard to sickness will be these points :—

1. How many men am I losing daily from the rank and file actually serving with the colours?

2. How many are replaced by discharge from hospital?

3. What is the balance, gain or loss?

4. If my effective force loses daily, when this balance is struck, such a percentage, what will be its loss of strength in a week, in four weeks, in six weeks? &c.

5. What are the causes, *i.e.*, what are the diseases which are causing this sickness, and how are they affected by special circumstances of age, particular service, or arms, or other causes?

The mortality in war should be calculated on the mean strength, that is, on the total number of healthy and sick, and on the sick alone, so as to represent both the loss of the army and the fatality of the sickness.

Sub-Section III.—Mortality Rates in Prisons.

A reference having been made from India as to the best method of calculating the mortality, the following formulas are laid down by Dr Farr,* which it will be useful to quote :—

Formulas.

P = Average number of prisoners, or mean population of the gaols, obtained by taking the sum of the daily numbers, and dividing by 365 (or 366 in leap year).
D = Deaths of prisoners in a year.
A = Annual admissions.
E = Exits, either by discharge or death, annually.
S = Average numbers on the sick list.
C = Cases of sickness occurring in the year.
m = Mortality rate.

Then :—

(1.) $\frac{D}{P} = m_1$; and $100\, m_1$ = annual rate of mortality per cent.

(2.) $x = \frac{P}{A}$ = average term of residence in years or fractions of a year. Multiply x by 365 or 366, and we have the term in days.

But $\frac{D}{A} = m_2$ = the death-rate in the time x, then, population being constant, the mortality is proportional to time.

$$m_2 : m_1 : : x : 1.$$

$$\text{And } m_2 = x m_1 = \frac{P}{A} \cdot \frac{P}{D} = \frac{D}{A} \therefore m_1 = \frac{m_2}{x} =$$

$$\frac{D}{A} \cdot \frac{A}{P} = \frac{D}{P} = \textit{annual rate of mortality.}$$

The mortality rate, it is assumed, is constant and proportional to the time. If the admissions (A) do not equal the exits (E), then $\frac{A + E}{2}$ may generally be substituted for A in the preceding equation.

* Report of the Army Sanitary Commission on Methods of estimating the Mortality in Indian Prisons.

(3.) $\frac{S}{P} = s_1$ = average sickness rate; and 100 s_1 = proportion of constantly sick to every 100 prisoners.

(4.) $\frac{C}{P} = c_1$; and 100 c_1 = the cases of sickness per annum to every 100 of the gaol population.

(5.) $\frac{D}{C} = m_3$; and 100 m_3 = deaths to every 100 sick cases.

(6.) $\frac{D}{S} = m_4$; and 100 m_4 = annual rate of mortality per cent. among the sick population of the prisons.

Statistical Forms used in the Army.

War Office No.	Title of Form.	Used by.
294	Weekly return of sick.	All medical officers in charge of troops at home.
294,A	" "	" " abroad.
294,B	Sick on board ship.	" " on board ship.
1060	Weekly return of invalids.	P. M. O's. at each home station.
1067	Annual do. do.	" "
1118	Monthly vaccination return.	All medical officers in charge of troops at home.
298	Annual return of sick.	Medical officers at home and abroad.
1038	" " recruits.	" at home.
151,B	" " operations.	" at home and abroad.
298,A	" " deaths.	" "
298,B	" " men of other corps.	" "
823	" " casualties.	P. M. O's. at foreign stations.
273	" " military prisons.	Medical officers in charge of prisons.
151	Return of wounds and injuries received in action.	On active service only.
151,A	" "	On active service only.
892	Quarterly return of sick.	P. M. O's. at home stations.
893	" "	" foreign.
196	Return furnished to regimental medical officers by officers commanding, to accompany annual return of sick.	Home.
197	" "	Abroad.
198	" "	Depôts at home.
Books	Admission and discharge.	Medical officers at home and abroad.
...	Certificate books.	" "

BOOK II.

THE SERVICE OF THE SOLDIER.*

In the First Book, the general principles of Hygiene were illustrated, as far as possible, by examples drawn from the life of the soldier; but this does not exhaust the subject. It is necessary to consider a little more particularly the nature of the service of the soldier, and the influence it has on him. At the same time, it will be unnecessary to return to various points already sufficiently discussed in previous chapters.

The life of the soldier is conveniently divided into five epochs: the period of entrance on his new life, and his first year's service—his service at home—abroad—on board ship—and during war. These five chapters include all that is important.

CHAPTER I.

THE RECRUIT.

In the English army, young men are enlisted at or after seventeen or eighteen years of age,† unless they are intended for drummers. They must be of a certain height, which is fixed by regulation from time to time, according to the particular arm, and to the demands of the service. There must also be a special girth of the chest, which is in proportion to the age and height.

In time of war, the measurements are reduced according to the demand for men; and even in time of peace, the necessary height of the infantry recruit, usually 65 or 66 inches, has been sometimes only 5 feet 4 inches. Before the enlistment is completed, the recruit is examined by a medical officer, and then by the staff-surgeon of the recruiting district, according to a scheme laid down in the Medical Regulations.‡ The scheme is a very good one, and

* I may refer army medical officers to "Army Hygiene," a work published by Deputy-Inspector General Dr C. A. Gordon, C.B., as giving a good account of transport and many other points, which the size of this portion of the manual prevents me from treating at great length.

† In reality, they sometimes enlist under this age.

‡ For a full account of the system of recruiting, the mode of examination, and much useful information on disabilities, see a paper by Dr Crawford in the "Army Medical Report for 1862."—*Blue-Book*, 1864.

aims at investigating, as far as can be done, the mental condition; the senses; the general formation of the body, and especially of the chest; the condition of the joints; the state of the feet; the absence of hernia, varicocele, piles, &c.; and the condition or physical examination of the heart, lungs, and abdominal organs generally.* A certain girth of chest according to the height is required.

After joining his regiment he is again examined, and may be rejected if any defect is discovered. Rejections may take place then either at the primary or secondary inspection.

Both the average weight and height, especially the latter, will vary with the demand for men.

The trades of the men furnishing the recruits must also vary greatly from year to year.

Of every 1000 recruits from all parts of the kingdom, labourers, husbandmen, and servants, furnish about one-half; mechanics employed in occupations favourable to physical development, about one-sixth; manufacturing artisans (as cloth-workers, weavers, &c.), about one-sixth; shopmen, a little less than one-tenth; and the remainder is made up of professional occupations, students, and boys.†

The number of recruits drawn from each division of the kingdom varies with the state of trade, degree of distress, emigration, &c. In 1860–1862, of every 1000 recruits, 553 were English, 127 Scotch, 314 Irish, and 6 foreign and colonial. Of late years the Irish have declined in numbers, in 1867 there were only 172·6 Irish per 1000 of recruits.

After the recruit has been enlisted and approved, he joins his depôt or his regiment; receives his kit, which he subsequently in part keeps up at his own cost; and is put on the soldier's rations. He enters at once on his drill, which occupies from 3½ to 4½ hours daily. Wherever gymnasia are established, he goes through a two-months' course of gymnastic training for one hour every day. He then goes to rifle drill, which lasts about six weeks, and then joins the ranks. After the rifle drill, he has another month's gymnastic training, and is then supposed to be a finished soldier.

The total number of rejections, either at once or after re-examination by a second medical officer, on various grounds, of men brought by the recruiting serjeant to the medical officer, varies somewhat from year to year. The ratio in 1860–61 was 293 per 1000, in 1862, 401, and in 1863, 441 per 1000 in each year. In 1866, no less than 540, and in 1867, 524 were rejected per 1000 inspected. Of these rejections, some are primary (*i.e.*, at once by the examining officer), and some secondary (*i.e.*, by the staff-surgeon of the district or at the head-quarters of the regiment).

About ⅝ths of the rejections arise from causes connected with general bad health or feeble constitution, and ⅛th from causes affecting the marching powers of the men (Balfour).

In the French army, the height was fixed in 1860 at 69 inches (1·76 metres) for the carabiniers, and 61½ inches (1·56 metres) for the infantry of the line.

The rejections in the French conscription include men rejected for insufficient height, as well as reasons of health.‡

Such being the system, it will be desirable to consider certain points.

* As the Medical Regulations are in the hands of all medical officers, it is unnecessary to go into more detail on this point. My colleague, Professor Longmore, uses in the Army Medical School a set form of examination, which renders it almost impossible that any point should be overlooked.

† The average weight and height of the British recruit are carefully given by Dr Balfour in the Army Medical Department Reports, which may be referred to.

‡ Sistach, "Recueil de Mém. Mil." 1861, Nov., p. 353.

1. *The Age of the Recruit.*—Strong opinions have been expressed by Ballingall (English army), Lévy (French army), Hammond (American army), and other army surgeons, that the age of 17 or 18 is too low—that the youngest recruit should be 20 or 21 years of age.

This opinion is based both on actual experience of the effect produced on boys of 17 to 20 when exposed to the hardships of war, or even to heavy duty in time of peace, and on a physiological consideration of the extreme immaturity of the body at 18 years of age.

With regard to the first point, there is no doubt that to send young lads of 18 to 20 into the field, is not only a lamentable waste of material, but is positive cruelty. At that age such soldiers, as Napoleon said, merely strew the roadside and fill the hospital. The most effective armies have been those in which the youngest soldiers have been 22 years of age.

With regard to the second, it is also certain that at 18 the muscles and bones are very immature, and, in fact, it is not till 25 years of age, or even later, that all epiphyses of the bones have united, and that the muscles have attained their full growth.*

The epiphyses of the transverse and spinous processes of the vertebræ hardly commence to ossify before 16 years of age, and it is not till after 20 years that the two thin circular plates form on the body of the vertebræ. The whole process is not completed till close on the 30th year. The consolidation of the sacrum only commences at the 18th year, and is completed from the 25th to the 30th year. The fourth and third bones of the sternum are only united between the 20th and 25th years, and the second is not united to the third bone before the 35th year. The epiphyses of the ribs commence to grow between the 16th and the 20th years, and are completed by the 25th year. The epiphyses of the scapula join between the ages of 22 and 25. The epiphysis of the clavicle begins to form between the 18th and 20th years. The internal condyle of the humerus unites at 18, but the upper epiphysis does not join till the 20th year. The epiphyses of the radius and ulna, the femur, the tibia, and fibula, are all unjoined at 18 years, and are not completely joined till 25 years. The epiphyses of the pelvic bones (viz., crest of ilium, spine, and tuberosity of the ischium) begin to form at puberty, and are completed by the 25th year.†

That the muscles are equally immature is just as certain; they grow in size and strength in proportion to the bones.

These facts show how wrong it is to expect any great and long-continued exercise of force from men so young as 18 and 20, and what will be the inevitable consequences of taxing them beyond their strength.

Are we, then, to conclude that the soldier should not be enlisted before 20?

It appears to me that the case stands thus. If the State will recognise the immaturity of the recruit of 18 years of age, and will proportion his training and his work to his growth, and will abstain from considering him fit for the heavy duties of peace and for the emergencies of war till he is at least 20 years of age, then it would seem that there is not only no loss, but a great gain, by enlisting men early. At that most critical period of life the recruits can be brought under judicious training, can have precisely the amount of exercise and the kind of diet best fitted for them, and thus in two years be more fully developed, and be made more efficient, than if they had been left in civil life.

2. *The Height and Weight of the Recruit.*—The desire of almost all military

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* See Aitken's "Growth of the Recruit and Young Soldier," 1862.

† See Aitken's "Growth of the Recruit," p. 37, and Quain's "Anatomy," for still fuller details.

officers is to get tall men. The most favoured regiments, especially the cavalry, get the tallest men. It has been recommended both that shorter men should be generally taken, and that the infantry should have the tallest men. The last point is one for military men to determine, and must be decided by considerations of the respective modes of action of cavalry and infantry.

The first point is entirely physiological, and opens a difficult question. What is the height, at 18 years of age, which is attended with the greatest amount of health, strength, and endurance, or is it possible to fix such a standard?

Tables of average height and weight have been compiled by Quetelet and much used, and lately somewhat similar tables have been framed by Danson, Boyd, and Liharzik.* M. Bernard has also given (Rec. de Mem. de Méd. Mil., Mai, 1868, p. 371) some useful papers on the height and weight of 400 men of the Chasseurs a Pied de la Garde. With regard to all of these it may be said that the observations (however numerous) are yet too few for such a large question, and that the influence of race has been too little regarded.†

Boyd gives the height at 18 years at 60·4 inches, and at 25 years at 67 inches, and Liharzik at the same ages give 64·17 and 68·9 inches. The English army returns (1860–67) give the heights of the recruits, but it must be understood that we cannot deduce the mean height of the population from these figures, as the shorter men are not taken as recruits.

Although the numbers are not very accordant, we may perhaps assume that at 18 the average height will be something near 64 or 65 inches, and the average weight about 124 ℔.

But the difficulty of the case only commences here; taking the age at 18 (for over 20 the case is simple), what is the range above and below the average which is consistent with perfect health and growth? How far is it safe to apply an average to an individual? Will not an excess of weight and height imply that an individual comes of a larger race, or has been better fed and nourished, and is so far a stronger man than he who only just reaches the average?

The following are the Averages given by Quetelet (Belgians) and by Danson (English criminals), at the Ages when Recruits are enlisted:—‡

Age.	Height.		Weight.	
	Quetelet.	Danson.	Quetelet.	Danson.
	Inches.	Inches.	℔ avoir.	℔ avoir.
16	57	...	109	...
17	64·3	...	116	...
18	65·2	64·34	126	122¾
19	...	64·94	...	130¾
20	65·9	65·11	132	131⅓
25	66·1	66·3	138	145⅔

The range, in fact, appears to be very great, as much as six inches above

* Liharzik's number professes to be based on a law induced from great numbers of measurements in different animals.

† Boudin, in a late paper on the size of the French conscript, is inclined to attribute differences in height more to race than to any other condition.

‡ In M. Bernard's essay just referred to, the mean age of 400 men of the foot Chasseurs of the Guard was 30½ years; the mean circumference of the chest 34·6 inches; the mean height 64·8 inches; and the mean weight 142·4 lb avoir. There were only 9 men between 18 and 21 years of age; the mean girth was 33 inches, the height 66 inches, and the weight 138 lb avoir. So that those 9 men were actually taller than the mean. This shows how small numbers might mislead.

and below the mean (Danson); *i.e.*, a boy at 18 may be 58 or 71 inches tall. But are these extremes consistent with perfect health, such as we demand in a recruit? It seems very doubtful if they are.

It may be well to put the same question in rather a different way. In the English army the minimum height has been always (except in times of great emergency) above the mean height of the population at that age. Has the State, then, secured a larger framed and more powerful set of men by only taking those who are above the mean height, or has it unnecessarily limited its choice?

The experience of other armies cannot answer this question. The French height of infantry is 61½ English inches, or 2½ below the mean. The Austrian height for infantry is 60 inches; in the Prussian army* the least height (in English inches) of the recruits for the cuirassiers is 65·9 inches, and the greatest 69 inches; for the light cavalry (hussars and dragoons), the least height is 63·8, the greatest 68 inches. In the Jäger battalions the height is 63·8 inches (English), and not more than 69 inches. Men of 60 inches are, however, exceptionably taken, if strongly built. In the infantry (not Jäger) the least height is 63·6 inches, but men of 60 inches are also occasionally taken. In the Northern American army the height of the infantry was, in 1863, fixed at 63 inches (Hammond), but men were really taken as low as 60 inches.†

It is therefore clear that the great military nations go 2 inches or even more below the mean height of the population at the recruiting age, and find no injury to the quality of their soldiers, and it would certainly appear unnecessary that the English should fix their standard at 1 inch above the mean height for infantry, and 2 or 4 inches for cavalry. But this does not settle the question, as it may still be argued that the taller men are most desirable when they can be procured, although shorter men may answer very well when others cannot be obtained. I really know of no good evidence which can settle this question.

The best rule to guide us is that given by Dr Aitken, viz., to take into consideration the three points of age, height, and weight, and if either in weight or height, or both together, there is any great divergence from the mean, then something wrong will probably be found. But as long as weight and height are in accord, the taller and heavier the man the better, as a rule.

One point is, however, quite clear. When the height is much below the mean, the bodily development generally is bad. Hammond states that, in the American war, men of less than 5 feet have broken down by a few weeks' campaigning, while men of 5 feet have stood the work well. Probably 62 inches at 18 years of age, and 112 ℔ to 116 ℔ weight, should be a minimum, even in times of the greatest pressure. So also a very great height at 18 years of age is objectionable, and anything over 67 inches at that age should be looked on with great suspicion. As a rule, also, adult men of middle size (67 to 69 inches) appear to bear hard work better than taller men. There is one alteration in the regulations which would be desirable, viz., that the required height and weight at the respective ages should be expressly named; at present the minimum height for the whole range of years from 18 to 25 is alone stated in the Horse-Guards' Circular.

With regard to weight alone, the rule is simple. Unless there be any great disproportion in height, the heavier the recruit is the better; this will be found a rule with very few exceptions.

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* Prager. Das Preusissche Militair-Méd :-Wesen, 1864, p. 312.
† The minimum height of the Roman soldier was 62½ inches.

3. *The Physical Training of the Recruit.*—A great improvement has been introduced by the late order that each recruit shall have three months' gymnastic training. If properly done, this will have a most beneficial effect. The medical officer will have power to continue this if necessary, and care should be taken to use this power (see chapter on GYMNASTIC TRAINING for the points to be attended to by the medical officer).

It would be very desirable to make a rule that no soldier under 19 years of age should carry his pack, except on parades for inspection of kit; he should be excused the pack in marching out, field-days, and drills. Indeed, it may be questioned whether this rule should not be extended till 20 years of age. The young soldier under 19 or 20 years of age should also be excused from guard; heavy guard duty, even an amount which gives three nights in bed out of four, is too much for an immature frame. In fact, the soldier, till he is 20 years of age, should be spared all heavy duty. The time thus saved would be well spent in other matters presently to be noted.

4. *The Mental Training.*—Since the introduction of rifle practice, the trade of the soldier has become much more interesting to him; he is now taught scientifically how to manage his arm, and learns to take interest in his shooting. It would be most desirable to give him some knowledge of the Military Art, and of the object of the different manœuvres he goes through. A military literature fitted for the private soldier is still wanting. It is also very important to train him for the field, and to teach him to perform for himself all the offices which in time of war he will have to do—not merely trench work, but hutting, cooking, washing and mending his clothes, as in time of war (see WAR). It is too late, at the commencement of a campaign, to begin these necessary parts of a soldier's education; they should form part of his training as a recruit; and if he is excused guard and other duties during his first year, there would be ample time.

Great attention is now being directed to the importance of soldiers keeping up their trades, or learning some trade if they have none. Such a system occupies men, makes them contented, keeps them from dissipation, and opens a career for them when they leave the army. Instead of interfering with their military training, it can be made to subserve it, and possibly might be found to be advantageous to the State, even in a pecuniary point of view. The recruit then would have to keep up or learn his trade.

5. *The Moral Training.*—The recruit, on entering the army, is brought under moral influences of a strong kind. A discipline always rigorous, and sometimes severe, produces often a ready obedience and a submission of character, and, when not carried too far, greatly improves him. At the same time, independence is preserved by the knowledge which the soldier has of his rights and privileges, and the result is a manly, conscientious, and fine character. But occasionally, a too sensitive nature on the part of the recruit, or a discipline too harsh or capricious on the part of his officers, produces very different results, and the soldier becomes cunning, artful, and false, or morose and malicious. The two characters are often seen well marked in old soldiers, and no contrast can be greater than between the two. A heavy responsibility rests, then, with the officers of the army who have power thus to influence, for good or evil, natures like their own.

The influence of companionship is also brought to bear on the recruit, and is fraught with both good and evil. The latter probably predominates, though there are many excellent, high-minded, and religious men in the army. Indeed, in some regiments the proportion of steady religious men is perhaps beyond the number in the analogous class in civil life. But if the influences be for bad, the recruit soon learns some questionable habits and some vices.

Thus he almost invariably learns to smoke, if he has not acquired this habit before. It is indeed remarkable what a habit smoking tobacco is in every army of Europe; it seems to have become a necessity with the men, and arises probably from the amount of spare time the soldier has, and which he does not know what to do with. A recruit, on joining, finds all his comrades smoking, and is driven into the habit.

The discussion on the effects of tobacco does not seem to have led to any clear conclusions. The immoderate use brings many evils to digestion and circulation especially. But no great evil appears to result from the *moderate* use, though no good can be traced to it. In moderation it has not been proved to lessen appetite, to encourage drinking, or to destroy procreative power. But, on the other hand, it probably lessens bodily, and perhaps even mental, activity, in spite of the illustrious examples to the contrary. It is certainly remarkable how uniformly the best trainers prohibit its use, and men of the highest physical vigour are seldom, I believe, great, and often are not even moderate, smokers. As it is of no use, and indeed injurious, by bringing men under the thraldom of a habit, it seems very desirable to discourage it.

But in the army it seems useless to fight against this custom, nor is it indeed one which is sufficiently injurious to be seriously combated, except for one reason. In time of war, the soldier often cannot obtain tobacco, and he then suffers seriously from the deprivation. The soldier should have no habits which he may be compelled to lay aside, and which it would pain him to omit. As the time of the soldier becomes more and more occupied with his vocation and with a trade, it is possible that the amount of smoking may lessen.

A much more serious matter is the vice of drinking, which many recruits are almost forced into, in spite of themselves. The discipline of the army represses much open drunkenness, though there is enough of this, but it cannot prevent, it even aids, covert drinking up to the very edge of the law. Formerly, a most lamentable canteen custom made almost every man a drunkard, and a young boy just enlisted soon learned to take his morning dram, a habit which, in civil life, would mark only the matured drunkard. Now, happily, spirits are not sold in the canteens, and no regulation thrusts raw spirits down a man's throat.

Drinking is, however, still the worst vice of the army, and that which strikes most of all at the efficiency of the soldier.

How is this great vice to be combated? The Duke of Wellington, in 1845, abolished teetotal societies in regiments, in accordance with the general principle of allowing in the army no form of combination. The great influence of a common cause and enthusiasm cannot therefore be used. We must look to the same causes to remove drunkenness in the army as in civil life; an improved tone in this respect among officers; the influence of officers, and especially medical officers, with their men; more occupation for the men, and the establishment of reading-rooms and soldiers' institutes, which, in several places, have done marvels in lessening drinking.

Another vice is almost as certainly contracted as smoking by the recruit. Probably, before enlistment, he has led no very pure life, but when he enters the army, he is almost sure to find his moral tone higher than that of some of his new associates. A regiment, in fact, is composed of young men with few scruples and small restraints. Prevented from marriage, and not able, indeed, to look forward to it, as civilians do; tempted by low prostitutes, who to the disgrace of our laws, are permitted to hang about every barrack, and to haunt every neighbouring public-house, it is no wonder if, to the extent of

his means, the soldier indulges in promiscuous sexual intercourse. He does this, in fact, to excess, and the young recruit is led at once into similar habits. That many recruits are most seriously injured by this habit, even if they neither contract syphilis nor gonorrhœa, is, I believe, certain. The remedies for this have been already discussed.

It has also been supposed that solitary vice is particularly rife in armies. I am unaware of any evidence on this point, and believe that, in the English army, such habits are uncommon.

6. *The Amount of Sickness and Mortality suffered by the Recruit during the First Six Months and Year of Service.*—This is an extremely important matter, but at present we are not able to answer the question for the English army.

In the French army,* the amount of sickness among soldiers under one year of service is more than one-third greater than among the army generally; this is partly caused by slight injuries, though not solely, for the admissions to hospital† are nearly one-fourth more among them than in the army at large. The mean of five years (1862–66) gives a mortality in the French army among soldiers under one year's service of 12·26, which is nearly one-fourth more than the total mortality of all ages.

A School for Recruits.—Looking to the very great importance of properly training the recruit in all ways, and recognising the fact that an army badly recruited was never yet made a good one, it may be questioned whether the present system of enlisting a man for a particular regiment, and sending him at once to his regiment or depôt, is the best that can be adopted. It would seem much wiser to conduct his physical training altogether apart from the older men, to give him a different and more nutritious diet than the full-grown man requires, and to secure him, as far as can be, from the bad influences of injurious companionship.

In a school for recruits, not only could physical, mental, and moral training be much better conducted than under the present system, but men might be selected for the different arms of the service; weakly men might be got rid of, or employed in the corps requiring least vigour of body.

Six months' training at such a school would be the best possible initiation, nor would the State lose any period of service in reality. If the recruit entered the ranks at six months instead of three, the trifling loss would be far more than compensated by the greater vigour and the lessened sickness.

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* Statistique Médicale de l'Armée pendant l'Année 1862. Paris, 1864, p. 11. Ibid. pendant l'Années, 1863, 4, 5, and 6.

† The French treat some cases in barracks, some in the regimental infirmaries, some (the severe cases) in general hospitals.

CHAPTER II.

HOME SERVICE.

The recruit having entered the ranks, begins his service, we will assume, at home. This does not necessarily follow, for he may be soon sent out to his regiment serving abroad. Usually, however, he is kept at his depôt as long as possible. It would be desirable, however, to make a rule that the first two years of service should always be at home. In previous chapters, the food, clothing, housing, &c., of the soldier have been discussed, so that I have now merely to describe the effects of the life upon him.

We should suppose the life would be a healthy one. It is a muscular, and, to a certain extent, an open-air life, yet without great exposure or excessive labour; the food is good (though there might be some improvement), the lodging is now becoming excellent, and the principles of sanitation of dwellings are carefully practised. Although the mode of clothing might be improved as regards pressure, still the material is very good. There is a freedom from the pecuniary anxiety which often presses so hardly on the civil artisan, and in illness the soldier receives more immediate and greater care than is usual in the class from which he comes.

There are some counterbalancing considerations. In a barrack, there is greater compression of the population than in the most crowded city, and beyond a doubt the soldier has greatly suffered, and even now suffers, from the foul air of barrack rooms. But this is a danger greatly lessening, owing to the exertions of the Barrack Improvement Commissioners, and, as is proved by the experience of some convict jails, can be altogether avoided.

Among the duties of the soldier is some amount of night-work; it is certain that this is a serious strain, and the Sanitary Commissioners, therefore, inserted in the Medical Regulations an order that the number of nights in bed should be carefully reported by medical officers. Commanding officers should be informed how seriously the guard and sentry duties, conducted as they are in full dress, tell on the men if they are too frequent; one guard-day in five is quite often enough, and as there are often unnecessary posts, four nights in bed can usually be secured to the men, if the commanding officer is impressed with the importance of this matter.

The weights and accoutrements are heavy, and of late years a practice has crept in of making the infantry soldier carry his pack much more frequently than formerly. Twenty years ago he merely paraded twice a-week in heavy marching order for inspection. Now, he often carries his pack on field-days, sentry, and even regimental drill. Instead of accustoming men to the pack, and making it easier, it breaks them down; but as alterations are now being made, this cause of disease will disappear.

The habits of the soldier are also unfavourable to health; in the infantry, especially, he has much spare time on his hands, and *ennui* presses on him. *Ennui* is, in fact, the great bane of armies; less in our own than in many

others. It is said to weigh most heavily on the German, the Russian, and even on the French army. Hence, indeed, part of the restlessness, and one of the dangers of large standing armies. The Romans appear to have avoided this danger by making their distant legions stationary, and permitting marriage and settlement—in fact, by converting them into military colonies. We avoid it in part by our frequent changes of place, and our colonial and Indian service; but not the less, both at home and abroad, do idleness and *ennui*, the parents of all evils, lead the soldier into habits which sap his health. Not merely excessive smoking, drinking, and debauchery, but in the tropics mere laziness and inertia, have to be combated. Much is now being done by establishing reading-rooms, trades, industrial exhibitions, &c., and by the encouragement of athletic sports to occupy spare time, and already good results have been produced.

The establishment of trades, especially, which will not only interest the soldier, but benefit him pecuniarily, is a matter of great importance. It has long been asked why an army should not do all its own work; give the men the hope and opportunity of benefiting themselves, and *ennui* would no longer exist. In India, Lord Strathnairn did most essential service by the establishment of trades; and the system, after long discussion and many reports, is now likely to be fully tried in England.

Every military officer should remember that one of the proofs of ability for command and administration is the power of occupying his men, not in routine, but in interesting and pleasant work, to such an extent that rest and idleness may be welcomed as a change, not felt as a burden. Constant mental and much bodily movement is a necessity for all men; it is for the officers to give to their men an impulse in the proper direction.

Among the conditions of the soldier's life adverse to health, enforced celibacy must be reckoned. This produces not merely promiscuous intercourse, that terrible evil, but other effects. We do not require the statistical proof that both in the army and civil life married men have less illness and longer lives than single men; we might be certain, *a priori*, that the great function of procreation cannot be thus endangered by the conditions we impose on our soldiers without injury. The continental system of conscription for limited periods has prevented this matter from assuming the importance it does in armies enlisted for long or permanent service, but as the soldier's trade is now becoming a skilled one, and as he will be retained for longer periods, it cannot be doubted that the great military powers will in a few years have to meet this difficult problem.

For our own army the question is already pressing enough, nor is it easy to offer a solution; it can only be hoped that some great soldier who has, what all great soldiers ought to have, a conviction of the importance and a knowledge of the laws of health, may be found to reconcile the demands of military service with the dictates of a rule of nature.

The last point which, probably, makes the soldier's life less healthy than it would otherwise be, is the depressing moral effect of severe and harassing discipline. In our own army in former years, it is impossible to doubt that discipline was not merely unnecessarily severe, but was absolutely savage. An enlightened public opinion has gradually altered this, and with good commanding officers, the discipline of some regiments is probably nearly perfect; that is to say, regular, systematic, and unfailing; but from its very justice and regularity, and from its judiciousness, not felt as irksome and oppressive by the men.

The general result of the life at home on soldiers must now be considered.

It is by no means easy to say whether soldiers enjoy as vigorous health as the classes from which they are drawn; the comparison of the number of

sick, or of days' work lost by illness by artisans, cannot be made, as soldiers often go into hospital for slight ailments which will not cause an artisan to give up work. The comparative amount of mortality seems the only available test, though it cannot be considered a very good one.

Following the order laid down in the chapter on STATISTICS, we have to consider—

SECTION I.

THE LOSS OF STRENGTH BY DEATH AND INVALIDING, PER 1000 PER ANNUM.

A. BY DEATH.

It is to be understood that the mortality is here reckoned on the strength, that is, on the number of healthy persons actually serving during the time. The mortality on the sick is another matter.

From the Parliamentary Statistical Returns of the Army (1840 and 1853, which include the years 1826–1846), we find that the mortality among the cavalry of the line was about ⅓d more than among the civil male population at the same age (nearly as 15 to 10* per 1000), among the Foot Guards more than double (very nearly 20½ per 1000 as against 10), among the infantry of the line ⅘ths more (or 18 per 1000 as against 10).

The State was thus losing a large body of men annually in excess of what would have been the case had there been no army, and was therefore not only suffering a loss, but incurring a heavy responsibility.

In the splendid men of the Household Brigade, diseases of the lungs (including phthisis) accounted for no less than 67·7per cent. of the deaths, in the cavalry of the line for nearly 50 per cent., and in the infantry of the line for 57 per cent.; while among the civil population of the soldier's age, the proportion in all England and Wales was only 44·5 per cent. of the total deaths. The next chief causes of death were fevers, which accounted in the different arms of the service for from 7 to 14 per cent. of the total deaths. The remainder of the causes of deaths were made up of smaller items.

These remarkable results were not peculiar to the English army. Most armies did, some still do, lose more than the male civil population at the same age. The following are the most reliable statistics :— †

	Army Loss. Per 1000.
France (1823),	28·3
France (Paixhans, 1846),	19·9
France, mean of 5 years, (1862–66),	9·91
French in Algeria (1846),	64
,, ,, (1862–66),	14·98
,, Italy (1862–66),	14·12
Prussian‡ (1846–1863, excluding officers),	9·69
Russian (series of years),	39
,, (1857–1861),	18·7
Austrian,	28
Piedmontese (1859),	16
United States (before the war),	18·8
Portuguese (1851–53),	16·5
Danish,	9·5

The old Hanoverian army was healthier, losing only 5·3 per 1000 as against 9·5 among the civil population of the same ages.

* In reality the deaths from the civil male population of the soldiers' ages (20 to 40) were below 10, and in the healthy districts much below; the case against the soldier is, therefore, even worse than it reads in the text.

† Meyne (Eléments de Stat. Méd. Militaire, 1859) gives some of these figures; others are taken from the reports of the different armies.

‡ Dr Engel, in Zt. des Königl. Preussisch. Stat. Bureaus, Augt. Sept. 1865, p. 214.

In these foreign armies the same rule holds good; fevers (chiefly typhoid in all probability) and phthisis were the great causes of mortality. In Prussia phthisis formerly caused 27 per cent. of the total mortality, but in that army phthisical men are sent home, and after a certain time are struck off the rolls, so that the army deaths are thus fewer than they would be if the men died at their regiments. In Austria phthisis caused 25 deaths out of every 100; in France, 22·9;* while in 1859, the proportion among the civil population was 17·76; in Hanover, 39·4; and in Belgium 30; though in the latter country the proportion among the civil population was only 18·97 deaths from phthisis per 100 of all deaths. In Portugal the mortality from phthisis constitutes 22 per cent. of the deaths,† while in the civil population the deaths are 12 per cent. of the total deaths. In these armies, also, fevers caused a greater number of the deaths than in the English army, even in the period referred to. In Prussia, 36; in France, 26;‡ in Belgium, 16·6; and in Hanover, 23·68 per cent. of all deaths were from fever (typhoid?). In Portugal only 3·9 deaths are from typhoid out of every 100 deaths; this is owing to its rarity in the country districts; it is common in Lisbon.

Nothing can prove more clearly that in all these armies the same causes were in action. And from what has been said in previous chapters, it may be concluded that the reason of the predominance of these two classes, lung diseases and typhoid fever, must be sought in the impure barrack air, and in the defective removal of excreta.

The Crimean war commenced in 1854, and ended in 1856. A large part of the army was destroyed, and a fresh force of younger men took its place. Soon afterwards, the great sanitary reforms of Lord Herbert commenced. In 1859 yearly statistical returns began to be published, and have now (1869) been completed to 1867 (nine years).

In these nine years the mortality of all arms underwent an extraordinary decrease from that of the former period.

Mortality per 1000 *per Annum.*

	From all Causes.	From Disease alone (*i.e.*, excluding violent deaths).
Mean of nine years, 1859–67,	9·419	8·534
Highest in 1859, . . .	9·965	...
Lowest in 1862, . . .	8·72	7·97

In the different corps of the service the mortality varies. In 1860, for example, the Household Cavalry lost only 4 men out of 1223, or at the rate of 3·28 per 1000 of strength; while the Foot Guards, in the same year, lost 9·48 per 1000, and the Depôt Battalions 14·86. In 1867 the Royal Engineers lost 4·56, the Foot Guards 6·89, and the Depôt Battalions 11·50 per 1000 of strength.

It is curious to observe that in the Prussian, French, and English armies the mortality is almost the same, viz., about 9·5 per 1000 present with the colours; it is slightly lowest in the English.

The diminution over the years previously noted (1826–46) is extraordinary. Three causes only can be assigned for it—the youth of the army, and a better selection of men; or a partial removal of the causes of diseases; or earlier

* This was in 1860; I have calculated this from Laveran's returns from eleven of the great garrisons. In 1863, the mortality from typhoid in the French army was 1·87 deaths per 1000 of effectives in France, 1·63 in Algeria, and 3·55 in Italy. In 1866 the mortality was 1·45 in France, 1·39 in Algeria, and 2·26 in Italy.

† Marques, reviewed in an excellent article in the British and Foreign Medico-Chir. Review for April, 1863.

‡ Laveran, in 1860, made the number 25·9 in the deaths from eleven garrisons.

invaliding, and the action of the limited Enlistment Act, so as to throw the fatal cases on the civil population.

The question of age has been examined and disposed of by Dr Balfour,* who has shown that the youth of the army does not account for the lessening. Selection has always been made with equal care, and invaliding, though it certainly has been greater of late years, does not appear to have been in excess sufficient to account for the lessening. There can be no doubt, then, that the great result of halving the yearly loss of the army by disease has been the work of Lord Herbert and the Royal Sanitary Commission.

It will be observed that the diminution in the mortality in the French army has also singularly lessened from 1846 to 1862 and 1863, and this is, no doubt, owing to the great sanitary precautions now taken in that army.

Of the different arms of the service, the cavalry and artillery are rather healthier than the infantry; the engineers than either; the officers always show less mortality than the non-commissioned officers and privates, and the non-commissioned officers less than the privates.

Comparison with Civil Population.

This gross mortality must now be compared with that of the civil population. In England the gross male civil mortality at the soldier's ages is—†

	Mortality per 1000 of Population.
From 20 to 25 years of age,	8·83
25 to 35 ,,	9·57
35 to 45 ,,	12·48

The soldier's mortality, taken as a whole, is therefore not above that of the civil population, but then there is invaliding, and some uncertain addition should be made to the mortality on this account.

Comparing the soldier's mortality (invaliding being disregarded) with trades, he is rather more unhealthy than carpenters (7·77), labourers (7·92), bakers (7·94), blacksmiths (8·36), grocers (8·4), farmers (8·56), weavers and cotton-spinners (9·1), and shoemakers (9·33).‡ But he is healthier than butchers (9·62), miners (9·96), tailors (11·62), and publicans (13·02).

Influence of Age on the Mortality.

The following table from Dr Balfour gives the results, excluding the depôts:—

	Per 1000 of Strength.					
	Under 20.	20 and under 25.	25 and under 30.	30 and under 35.	35 and under 40.	40 and upwards.
1859–66,	3·01	5·78	7·90	12·09	16·02	19·6
1867,	3·04	5·06	6·83	13·35	13·19	15·48
Civil male population in England and Wales,	7·41	8·82	9·21	10·23	11·63	13·55
Healthy districts,	5·83	7·3	7·93	8·36	9·00	9·86

* Report for 1859, p. 6.

† In France, in 1866, the mortality was—

Years.	Per 1000 of Population. With Military Deaths.	Military Deaths excluded.
20 to 25,	10·12	10·1
25 to 30,	9·5	9·47
30 to 35,	9·7	9·68

Vallin in Ann. d'Hyg., Jan. 1869, p. 84. The year was, however, a choleraic year.

‡ Dr Farr's numbers, in the Supplement to the 25th Report of the Registrar-General, p. xvi.

The number of soldiers under 20 years of age is so small that no conclusions can be drawn; but it would appear that from 20 to 30 the mortality is favourable to the soldier, but after that the proportion is reversed, and the soldier dies more rapidly than the civilian. And if to this we call to mind the invaliding from the army, it seems clear that a prolonged military career must be decidedly injurious.

Causes of the Mortality.

In order to see the principal causes of the nine deaths which occur annually among 1000 men, I have calculated the deaths from each cause among 100 deaths.* Although this plan has disadvantages, it answers the purpose better than any other of bringing into marked contrast the ratio of the various causes of deaths *inter se.* I have placed side by side a table of the French army, which, however, represents the deaths in Algeria and Italy, as well as in France.

Ratio of certain Causes of Deaths to 100 *Deaths from all Causes.*

British Army at Home—1859-66—eight years.			French Army—Home, Algeria, Italy—1863-66—four years.		
Order.	Diseases in order of Fatality.	Per cent. of Deaths.	Order.	Diseases in order of Fatality.	Per cent. of Deaths.
1	Tubercular diseases—scrofula, phthisis, and hæmoptysis (chiefly phthisis), ...	33·806	1	Phthisis (chronic bronchitis included), . .	20·83
2	Diseases of heart and vessels,†	9·008	2	Typhoid fever, . . .	16·57
3	Diseases of the nervous system, exclusive of delirium tremens, .	6·596	3	Intermittent and remittent fevers, . .	7·19
4	Pneumonia, ...	6·540	4	Dysentery and diarrhœa, ...	6·76
5	Violent deaths, exclusive of suicides and executions, . . .	6·325	5	Acute pulmonary affections (pneumonia, bronchitis, pleurisy, pulmonary apoplexy),	6·33
6	Fevers—typhoid, typhus, and continued (chiefly typhoid), .	5·685	6	Cholera, ...	6·10
7	Acute bronchitis, . .	3·197	7	Wounds, ...	3·06
8	Suicides, ...	3·030	8	Smallpox, ...	1·54
9	Chronic bronchitis, .	2·270	9	Heart diseases, . . .	1·47
10	Delirium tremens, . .	·900	10	Mental diseases, . .	·72
	All other causes, . .	22·553		All other causes (violent deaths are not included), ...	29·43

This table shows very remarkable differences between the two armies. Of course, in comparing these numbers, it is necessary not to attach to them more than their proper value. Thus it would not be right to conclude from this table that phthisis is more fatal in the English than the French army; the numbers merely show that there are other causes of death in the French army so active as to reduce the relative proportion of the phthisical deaths. We may, however, draw some conclusions when the numbers are large; thus there must be an enormous excess of typhoid fever in the French army, and a

* These numbers have been calculated from the numbers in the table, called Appendix I. in Dr Balfour's Reports in the Army Medical Department Blue-books.

† A little more than half of these deaths are from aneurism, chiefly of the aorta. In 1867 diseases of the circulatory system gave 1·39 deaths out of 9·4 per 1000, or no less than 14·78 deaths out of every 100.

great excess of heart and vessel disease in the English. The nervous diseases are small in the French army, and delirium tremens does not rank among the first ten most fatal affections.*

Returning now to the English army, it will be necessary to briefly notice the chief causes of death.

1. *Tubercular Diseases.*

The deaths from phthisis and hæmoptysis in the eight years ending 1866 averaged 3·1 annually per 1000 of strength, the highest annual ratio being 3·86, and the lowest 1·95. In addition to this there was invaliding for phthisis, and thus a certain number of deaths were transferred from the army to the civil population. The following table shows the exact numbers in four branches of the service (two cavalry and two infantry) in three years.

TABLE *to show the Deaths and Invaliding from Phthisis and Hæmoptysis in Household Cavalry, Cavalry of the Line, the Foot Guards, and Infantry of the Line in three Years*, 1864–66.

Phthisis and Hæmoptysis, taken from Abstract in Appendix of Dr Balfour's Report.	Household Cavalry.			Cavalry of Line.			Foot Guards.			Infantry of Line.		
	1864.	1865.	1866.	1864.	1865.	1866.	1864.	1865.	1866.	1864.	1865.	1866.
Died per 1000, . .	0	3·29	3·31	1·86	0·964	1·82	2·61	2·28	2·89	1·97	1·7	1·79
Invalided per 1000,	10·69	7·413	9·92	5·59	3·858	3·899	11·9	12·1	9·59	7·5	6·7	5·62
Total died and invalided per 1000, . .	10·69	10·703	13·23	7·45	4·822	5·719	14·51	14·38	12·48	9·47	8·4	7·41

This table shows a considerable difference between the branches of the service; the mortality and invaliding of the Foot Guards are much the highest, and then of the Household troops. The mortality from tuberculosis of the infantry of the line is very uniform, and below the mean mortality of

* The following interesting table of the mortality in the French army in France, according to length of service, from typhoid fever and phthisis, taken from the Statistique Médicale d'Armée, pendant l'année 1866, p. 46 (published in 1868). I have put in also the gross mortality and the deaths from suicides. It will be seen that typhoid fever is far more fatal (*i.e.*, more prevalent) among the young soldiers, and indeed declines with perfect regularity during the service, while phthisis and suicides almost as regularly increase with service.

French Army at Home.—Mortality per 1000 *of Strength.*

Service.	Total Deaths from Disease (1662–66).	Typhoid Deaths (1864–66).	Phthisical Deaths (1864–66).	Suicides (1862–64).
Less than 1 year, . .	12·26	4·37	1·02	·31
1 to 3 ,, . .	12·86	4·22	2·73	·30
3 ,, 5 ,, . .	10·88	1·80	2·03	·41
5 ,, 7 ,, . .	7·96	1·24	2·56	·53
7 ,, 10 ,, . .	7·19	·46	2·55	·77
10 ,, 14 ,, . .	7·50	·41	3·32	·8
Over 14 ,, .	9·04	·23	3·37	·91

This table shows that our pathological doctrine of the greater insusceptibility to typhoid as age advances is correct, and also that phthisis increases perhaps in proportion to the length of time the causes act, for it has not usually been supposed that either the frequency of, or the mortality from phthisis increases, from age alone, between 18 and 45 years, which are the limits in the table, to the extent here indicated.

the army at large. The mortality of the cavalry of the line is a little below that of the infantry, and the invaliding is much less.

It is quite clear (and the same thing is seen in the earliest records) that there is an excessive rate of mortality and invaliding from phthisis in the regiments serving in London, and especially in the Foot Guards, which points to some influences acting very injuriously upon them.

How does this mortality compare with that of the male civil population at the soldiers' ages?

Mortality from Phthisis.

Male civilians.*	Age.	
All England and Wales, . .	20 to 25	3·5
" " . .	25 " 30	4·0
" " . .	30 " 35	4·1
" " . .	35 " 40	4·1
" " . .	15 " 55	3·7
" " . .	25 " 45	4·02
London, ...	15 " 55	4·5
Worst districts in England, excluding hospitals,		5·0
Best districts in England, ...		1·96

The deaths in the army from phthisis and hæmoptysis do not exceed the deaths in the population generally. They are, however, much greater than in the best districts of England, though fewer than in the worst. But in the army there is invaliding also; that is, men with a fatal disease are discharged into the civil population. Taking this into consideration, as expressed in the table just given, it seems certain that phthisical disease is in excess in the army as compared with the male civil population.

Did the army suffer more from phthisis in former years than it does now? The following table will answer this question.

Deaths from Phthisis per 1000 *of Strength.*

	Years 1830–36 =7 years.	Years 1837–46 =10 years.
Household Cavalry, ...	7·4	6·28
Cavalry of Line, ...	5·29	5·65
Foot Guards, ...	10·8	11·9
Infantry, ...	...	7·75
Mean, ...	7·83	7·89

During these two periods, which make a total of seventeen years, the mortality was 7·86 per 1000, and there was no decline in the later as compared with the earlier period.

But as in the eight years ending with 1866 the mortality was only 3·1 per 1000, and (in 1867 the tubercular mortality was 3·27, or almost the same), there must have been an enormous excess of mortality in the earlier period, unless it can be explained in some way.

(*a.*) In the earlier periods the mortality from chronic bronchitis was included in the phthisical mortality. If a correction is made for this, the mortality of the latest period rises only to 3·3; so that will not explain the difference.

(*b.*) Was the invaliding more active in the last period, so as to lessen the deaths occurring in the army below what would have taken place without invaliding? I have not been able to learn the amount of invaliding in the earlier period, but I have been told there is no reason to think it was less

* Parliamentary Return of Annual Average Mortality during the Decennial Period, 1851–60, Feb. 1864; and Dr Farr's Report to the Sanitary Commission, p. 507.

than subsequently, but, on the contrary, it was very large from the Foot Guards. That invaliding cannot account for the difference is seen by the fact that the annual deaths per 1000 in the seventeen years ending 1846 (viz., 7·86) were actually almost as numerous (in the cavalry of the line more numerous) as deaths and invaliding together in the last period of three years ending 1866 (viz., 9·95).

(*c*.) The Limited Enlistment Act, by which a certain number of weakly men may possibly have left the army, has been in action in the last period. I cannot estimate the amount of this action, but it is in the highest degree improbable that it has much direct effect; for if a man of nearly ten years' service were ill with phthisis, he would be sure to get invalided, in order to enjoy his temporary pension for two or three years, and would not simply take his discharge.

(*d*.) The lessened age of the army at large, if the Limited Enlistment Act has produced that effect, might perhaps have had some effect, as mortality from phthisis increases with age in the French army, and possibly in our own; but this would never account for the astonishing difference; for in the French army the increase from phthisis of the men over fourteen years' service, as compared with those under, is only 1 per 1000 of strength.

I conclude, then, that there was a greater excess of the disorganising lung diseases classed as phthisis in the earlier period (1830–46). The amount of phthisis strongly attracted the attention of Sir Alexander Tulloch and Dr Balfour in 1839. They state that in the Equitable Assurance Company at that time the annual mortality (at the ages twenty to forty) from disease of the lungs was 3·4 per 1000; while in the years 1830–36 the mortality from disease of the lungs among the Foot Guards was no less than 14·1 per 1000, of which phthisis alone caused 10·8.*

How does our army contrast with others?

In France the deaths from phthisis and chronic bronchitis together amount to 2·75 per 1000 of "present," but some die "*en congé;*" and it is probable that there is at present as much phthisis in the French as in our own army. In the Prussian army the men are also discharged early, so that comparison is difficult.

In the Prussian army the mean yearly mortality from laryngeal and lung phthisis was 1·28 per 1000 of strength (years 1846–63); in 1000 deaths there were 13·57. I do not know the amount of invaliding.

We may conclude, then, with regard to phthisis—

1. That it was formerly in enormous excess in the army over the civil population, and particularly in the Foot Guards; in other words, a large amount of consumption was generated.

2. That there has been a great decline of late years, though there is still in all probability some excess.

What are the causes of this phthisical excess in the years 1830–46? It is noticeable that in the earlier periods all affections of the lungs were also in excess.

The phthisis was not owing to climate, for that is unchanged. Moreover, we shall hereafter see that the same excess was seen in the Mediterranean stations and the West Indies.

It was not owing to syphilis, for the amount of syphilis has rather increased than diminished, while phthisis has lessened.

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* In commenting on this fact the reporters say (Army Medical Report of 1839, p. 13): "If the aggregation of a number of men into one apartment, even though the space is not very confined, creates a tendency to this disease, then it clearly points out the propriety of affording the soldier as ample barrack accommodation as possible." Thus, even at that time, it was seen that no other cause but overcrowding could account for the great amount of lung disease.

It was not owing to bad food, for the food was the same in all the branches, and yet the amount of phthisis was widely different. Besides, the food has been comparatively little altered.

It can hardly have been the duties or clothing, for there has been no sufficient change in either to account for the alteration, unless the abolition of one of the cross-belts some years ago had some effect. But then this would have only affected the infantry.

It must have some conditions acting more on the Foot Guards than in the Household Cavalry, and less in the Line Regiments. Also it must have been acting in the troops stationed in the Mediterranean and the West Indies. There is only one condition common to all which seems capable of explaining it, and that the cause noticed in the Report of 1839, viz., overcrowding. This condition was, and is still most marked in the barracks of the Foot Guards, and least in the barracks of the Cavalry of the Line. It is the only condition which has undergone a very decided change both at home and abroad. This consideration, as well as those formerly noticed in the section on Air, seems to me to make it almost certain that the breathing the foul barrack atmosphere was the principal, perhaps the only, cause of this great mortality from lung diseases. If this be so, it shows that the Foot Guards are still the worst housed of any troops.

2. *Diseases of the Heart and Vessels.*

The fact that diseases of the circulatory system rank second as causes of death in the army at home may well surprise us. It is marked in all arms, as much in the cavalry as infantry. The ratio per 1000 of strength is ·908 (1859–67). In addition to these deaths there is a large amount of invaliding from this cause.

The following table is taken from the First Report of the Committee on Knapsacks:—

Invalided in the Years 1861–2–3.

Heart cases to total invalids from all causes			under 20	years of age,	1 in 5·45
,,	,,	,,	20 to 24	,,	1 in 6·44
,,	,,	,,	over 25	,,	1 in 8

It is difficult to compare the earlier and later statistical records, on account of the imperfect diagnosis of heart disease in the earlier periods.

In the French army the deaths from heart disease are about one-third of our loss. In the Prussian I am uncertain, but Engel* gives only ·31 deaths out of every 100 as owing to "organic disease of the heart." Pericarditis and aneurism are not included in this number.

Among the civil male population of the soldiers' ages the mortality is only half as much (nearly).

Dr Lawson† has calculated the deaths among the civil population from "pericarditis," "aneurism," and "heart disease," and finds them to be ·48 per 1000 of the population between the ages of 15 to 45. The army excess is especially in aneurism (which Dr Lawson finds to be eleven times more frequent among soldiers). Deducting this, there is still a slight excess of heart disease in the army; and if the invaliding is added, the proof of an actual excess of production of disease of the heart and vessels in the army is undoubted.‡

The production of this cardiac disease in the army begins early in the ser-

* *Op. cit.* p. 227.

† Army Med. Depart. Report, vol. viii. p. 550.

‡ Of course it may be said the diagnosis is better made in the army. I do not think that can have much influence, as heart disease is a favourite term in the civil returns, and it is more likely to be in excess of the truth than under it.

vice. In 1860–62 I calculated out the causes of invaliding in 6856 men. Of these 1014 were under two years' service. In the whole number the percentage of heart disease as the cause of the invaliding was 7·7; among the men under two years' service it was 14·23 per cent. As these men had presumably healthy hearts when they enlisted, the effect both of the military life in producing heart disease, and the greater suffering from it of young soldiers, seems certain.

The cause of this preponderance in the army of diseases of the circulatory organs is a matter of great importance. Whatever they may be, it is probable that they produce both the cardiac and the arterial disease.

The two most common causes of heart disease in the civil population are rheumatic fever in young, and renal disease in older persons. The latter cause is certainly not acting in the army, and the former appears quite insufficient to account for the facts. A great number of the men who suffer from heart and vessel disease have never had acute rheumatism; and if we refer the affection to slight attacks of muscular rheumatism, which almost every man has, we are certainly going beyond what medical knowledge at present warrants. The effect of lung disease in producing cardiac affections is also not seen in the army to any extent.

The influence of syphilis in producing structural changes in the aortic coats was noticed by Morgagni. In 114 post-mortem examinations of soldiers dying at Netley, Dr Davidson* found 22 cases of atheroma of the aorta. Of those 17 had a syphilitic history, 1 was doubtful, and 4 had had no syphilis, but had heart and lung diseases. Of the whole 114 cases, 78 had no syphilitic history and had 4 cases of atheroma, or 5·1 per cent.; 28 had a marked syphilitic history and 17 had atheroma, or no less than 60·7 per cent. This seems very strong evidence as to atheroma. With respect, however, to actual aneurism no corresponding analysis of cases has been made, and therefore at present the effect of syphilis must be considered uncertain; but it is quite clear, even admitting its influence, there is no reason to think that syphilis prevails more among soldiers than among the civil male population of the same class. There is no good numerical evidence on this head, but everything tends to show the amount of syphilis throughout the population to be great. It is therefore unlikely that an excess of syphilis, if it really occurs among soldiers, and if it actually predisposes to aneurism, as seems possible, could produce 11 times as many aneurisms as in civil persons.

The effect of excessive smoking again has been assigned as a cause of the soldier's cardiac disease; but no one who knows the habits of many continental nations, and of some classes among our own, could for a moment believe this to be the cause.

There is, however, one cause which is continually acting in the case of soldiers, and that is the exertion (often rapid and long continued) which some of the duties involve. The artillery have very heavy work; the cavalry also at times; and the infantry soldier, though his usual labour is not excessive, is yet sometimes called upon for considerable exertion, and that not slowly, or with rests, but with great rapidity. And this exertion is in all arms undertaken with a bad arrangement of dress and of equipments. The cavalry and artillerymen are very tightly clothed, and though the horse carries some of the burden, it is, I believe, undoubted that the men are overweighted. In the infantry, till lately, there were very tight-fitting tunics and trousers (which were often kept up by a tight belt); there was a broad strap weighed

* On Atheromatous Degeneration of the Aorta and its Association with Syphilis, by Staff-Surgeon Peter Davidson, Army Medical Department Report, vol. v. p. 481.

below with a heavy pouch and ammunition, crossing and binding down the chest; and there was the knapsack constricting the upper part of the chest, and hindering the air from passing into the upper lobes.

The production of heart disease ought not to be attributed solely to the knapsack, as is sometimes done; the knapsack is only one agency; the cross-belt was probably worse, and the tight clothes add their influence. But even with the knapsack alone the effect on the pulse is considerable. Thus, four strong soldiers carried the old regulation knapsack, service kit, great-coat, and canteen, but no pouch and no waist-belt (except in one man). The pulse (standing) before marching was on an average 88; after 35 minutes it had risen on an average to 105; after doubling 500 yards to 139, and in one of the men was 164, irregular and unequal. After the double they were all unfit for further exertion. In a fifth man, who was not strong, the 35 minutes' marching raised the pulse to 120 from 94; after doubling 250 yards he stopped; the pulse then could absolutely not be felt. In another series, the average pulse of four men, with the knapsack only, was 98 (standing), after one hour's march, 112; after doubling 500 yards, 141. If the pouch and ammunition is added the effect is still greater. I have taken the pulse and respirations after long marches, and found the effect still more marked. Walking, of course, will quicken the pulse and respiration in any man, but not to such an extent, and the sense of fatigue in unincumbered men is much less. In the Third Report of the Knapsack Committee are some experiments made by the Surgeon of the Royal Marines at Gosport. Twelve men, with an average pulse of 82·6, after running 500 yards without knapsacks, had an average pulse of 124 (highest, 144; lowest, 104). After running 500 yards with the old knapsacks, the average pulse was 148 (highest, 164; lowest, 132). All these experiments were made with comparatively light weights; but when the man is in full service order the effect is much greater still, and the rapidity of the pulse continues for a long time after the work is done.

In the lecture, formerly alluded to,* my colleague, Dr Maclean, put this matter most forcibly before the authorities, and I believe he is quite justified in the expression that one great cause of the cardiac (and perhaps of the aortic and pulmonary) disease in the army is to be found in exertion carried on under unfavourable conditions.

Happily, much has been lately done by the authorities to remove this cause; but still, especially in the mounted service,† changes appear to be necessary, and in all arms it is desirable that officers should allow their men to do their work under the easiest conditions, as regards clothes, weights, and attitudes, consistent with military discipline and order.

3. *The Nervous Diseases.*

These form a very heterogeneous class: apoplexy, meningitis, paralysis, mania, &c., are the chief headings. The proportion to 1000 of strength is about ·6. The deaths among the male civil proportion (ages 25 to 35) are 6·6 per cent of total deaths, so that soldiers do not appear to suffer more.

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* Royal United Service Institution Journal, 1863, vol. viii.

† The cardiac diseases are of the most varied kind. I have seen at Netley, in Dr Maclean's words, in one hour in the summer, when the hospital is full, almost all the combinations of heart affections. It has appeared to me that if anything gives the tendency to heart affections, then the dress and the accoutrements come in as accessory causes, and prevent all chance of cure. In some cases there is no valvular disease, and not much hypertrophy of the heart, but a singular excitability, so that the heart beats frightfully quick on the least exertion.

4. *Pneumonia and Acute Bronchitis.*

Table to show the admissions and deaths per 1000 of strength, years 1859–66.

	Pneumonia.		Acute Bronchitis.	
	Admissions.	Deaths.	Admissions.	Deaths.
Average, ...	5·128	·571	63·56	·285
Highest in eight years, .	7·130	·736	88	·350
Lowest in eight years, . .	3·96	·423	50·4	·240

The acute inflammatory diseases of the lungs give, therefore, a mean annual mortality of ·856 per 1000 of strength.

In the French army pneumonia gives a lower, and acute bronchitis a higher, mortality than in our own, but this is perhaps a mere difference of nomenclature.

The opinion that the military suffer more than the civil population from pneumonia is an old one. It is also generally believed that they suffer less in the field than in garrison. I have been unable to find statistics that satisfy me as to the amount among the civil population. In the European population, generally, Ziemsin* gives the deaths from pneumonia as 1·5; and Oesterlen,† 1·25 per 1000; but this includes all ages, and both sexes. Among men alone it is certainly greater than among women. In London, in 1865, the mortality from pneumonia, between the ages 20 and 40 (both sexes), was 1 per 1000 of population.‡

If this be correct, either the mortality among soldiers is below the civil mortality, for as men are more subject to pneumonia than women, the mortality among the civilian males would be greater than 1 per 1000, whereas the military mortality is only half this. The mortality among the army pneumonic cases (deaths to treated), amounts (average of eight years) to 11 per cent., and as this is very nearly the civil proportion, every 1000 of population in London gave nine cases of pneumonia, while 1000 soldiers gave only five. It may be said, however, that London is not a fair test; but as a place of residence for soldiers it does not appear to predispose to pneumonia, as will be seen from the following table:—

	Per 1000 of Strength, years 1864–66.	
	Foot Guards in London.	Infantry in the Kingdom generally.
Admissions from pneumonia, . . .	4	5·9
Deaths from pneumonia, . . .	·52	·6

The mortality to cases was, however, higher in London (12·9 as against 10).

Although I do not see that pneumonia (and acute bronchitis?) are more common or more fatal among soldiers serving at home than among civilians, the above figures show what a fatal disease pneumonia is, and how worthy of renewed study its causes are.

5. *The Class of Continued Fevers.*

The returns do not carefully distinguish the several forms, but practically the majority of the fatal cases of "continued fever" are from enteric (typhoid) fever.

There has been a great decline in this class of late. In the ten years

* Monat's Bl. für Med. Stat. 1857, and Schmidt's Jahrb. 1862, No. 3, p. 337.
† Med. Statist. 2d edit. p. 567.
‡ Vacher. Sur la Mort. en 1865, Paris, 1866, p. 137.

(1837–46) the average admissions were 62, and the deaths 1·72 per 1000 of strength. In the last eight years the admissions have averaged 22, and the deaths ·5 per 1000 of strength.

This mortality is decidedly below that of the male civil population of the same age, which amounts to 9·6 per cent. of total deaths, and very nearly 1 per 1000 of population.

During the last ten years no points have been more attended to in the army than pure water supply and good sewerage, and we see the results in this very large diminution of deaths from the rate of the former period, and in the fact that in this particular class of disease the soldier is far better off than the civil population. So also the cholera of 1866 passed very lightly over the army at home (only 13 deaths out of 70,000 men), although in former epidemics it had suffered considerably.

The decline of enteric fevers confirms most strongly the doctrine of its intimate dependence on bad sewage arrangements.

The greatest amount of typhoid fevers in the army is in the garrisons in the seaports, the least in the camps.

The other classes of disease causing mortality need no comment. Chronic bronchitis is no doubt to be chiefly referred to phthisis (using that term as a generic word to include various disorganising lung diseases), and delirium tremens, which still causes almost one death yearly in 1000 men, is a return which will, no doubt, gradually disappear.

The smaller items of mortality, making up 22 out of every 100 deaths, are various; erysipelas, pyæmia, syphilis, hepatitis (in men from foreign service), enteritis, rheumatism (from heart complication probably, but returned as rheumatism), diabetes, ebriositas, scarlet fever, and diphtheria, are a few of the many causes which carry off a small number every year. The cancerous and kidney diseases are very few, as we might expect from the age of the men.

To sum up the case as regards the present mortality on home service, it may be stated that for the last nine years (up to 1867, the last year we have returns), there has been no very great fall in the number of deaths. But there is still much to be done in respect of preventing disorganising lung disease, disease of the circulatory organs, and even fever, for we ought not to be satisfied until the term enteric fever is altogether obliterated. A renewed study of the causes of pneumonia is also necessary, in order to see if some way or other the attacks of that fatal disease cannot be lessened. There is no reason to think that we have yet touched the lowest possible limit of preventible disease; but, on the contrary, we can see clearly that the soldier, comparatively healthy as he is, may be made more healthy still. Some evidence in support of such a view may be found in the fact, that both at Gibraltar and in some of the West Indian stations the mortality has been lower in some years than it has ever been at home. But there is no reason why the home mortality should not be reduced to the standard of those foreign stations.

B. Loss of Strength of the Army by Invaliding.

The amount of invaliding is influenced by other causes than mere inefficiency of the men; sometimes a reduction is made in the army, and the opportunity is taken to remove weakly men who would otherwise have continued to serve. This was the case in 1861. As invaliding greatly affects the mortality of the army, a source of fallacy is introduced which it is not easy to avoid.

During the seven years (1860–66), there were invalided every year nearly 37 men out of every 1000, thus making a total loss by death and invaliding

from disease of nearly 46 men per 1000, or about $\frac{1}{22}$d part of the whole force. In 1867 the invaliding was lower, viz., 22·18 per 1000. The causes of the invaliding are now very carefully ascertained by Dr Balfour, and are inserted in his reports. Speaking in round numbers, phthisis and scrofula account for about $\frac{1}{4}$th of the invalids, and if chronic bronchitis is included, for nearly $\frac{7}{20}$ths, the two items of hypertrophia cordis and morbus valv. cord. account for $\frac{1}{10}$th, and chronic rheumatism for $\frac{1}{14}$th. The three nervous diseases of amentia, mania, and epilepsy always cause a large number of invalids, amounting nearly to $\frac{1}{10}$th, or almost the same as the two classes of heart diseases. All the other items are smaller.

SECTION II.

LOSS OF SERVICE FROM SICKNESS PER 1000 PER ANNUM.

(*a.*) *Number of Admissions into Hospital.*—On an average 1000 soldiers furnish rather under 1000 admissions into hospital per annum; 963 in nine years (1859–67). The number varies in the different arms from about 500 in the Household Cavalry, which is usually the lowest, to about 1400 in the Cavalry and Artillery Depôts. In the first case the steady character of the men, many of whom are married, and in the second the frequency of contusions during drill, accounts for this great range. In the Infantry the average is from 850 to 1020.

The number of admissions has remained tolerably constant for 25 years, although during that time the mortality has so much decreased, a fact which proves how inferior a test of health the number of admissions is. In no part of the world, indeed, have they a constant relation to the deaths.

The admissions in the French army are not comparable with ours; slight cases of sickness (which with us are often not recorded) are treated in barracks (*a la chambre*), severer but still slight cases in the infirmaries, bad cases in the general hospitals. The mean of five years (1862–66) give 2028 total admissions per 1000 of "present." The admissions to the infirmaries in France (in 1866) were 323 per 1000 "present;" to the hospitals, 306; making a total of the severer cases of only 629 per 1000 in that year. This shows how many slight cases there are in the French army.

In the Prussian army the average admissions (mean of 18 years 1846–63) were 1336.

(*b.*) *Daily number of Sick in Hospital per* 1000 *of Strength.*—About one-twentieth of the army is constantly sick in time of peace, or 5 per cent. The exact average in the years 1860–66 was 5·009, and in 1867 it was 4·247 per cent.

It is not possible to compare the army sickness with the civil population, or even with other armies.

In England, the number of members of friendly societies, between 20 and 30 years of age, who are constantly sick is nearly 16 per 1000.

In the French army, the mean sick in hospital are 29 per 1000 present; in both hospital and infirmary, 50; in the Prussian, 44; in the Austrian, 45; in the Belgian (1859), 54·2; in the Portuguese (1851–53), 39·4.

The number of daily sick has, of course, a wide range; sometimes an hospital is almost closed, at other times there may be more than 100 sick per 1000 of strength.

(*c.*) *Number of Days spent in Hospital per head in each* 1000 *of Strength.*—The number of days' service of a battalion 1000 strong in a year would be of

course (1000 × 365 =) 365,000. If we assume the average number of sick to be 51 per 1000, there are lost to the State (51 × 365 =) 18,615 days' service per annum, or 18½ days per man. As already said, it is difficult to compare the sickness of soldiers and civilians, but the above amount seems large when we remember that, in the friendly societies, the average sickness per man per annum (under forty years of age) is less than seven days.

Mean duration of Cases of Illness.—The number of days each sick man is in hospital (mean duration of cases) is nearly the same (18) as the number of admissions nearly equals the strength.

It can be most easily calculated as following: multiply the mean daily number of sick (sick population) by the number of days in the period, and divide by the cases treated. The number of "cases treated" is the mean of the admissions and discharges in the period.

Austrian army, 17 to 18 days.
French at home, all cases (1862–66), 7·97 days.
French in hospitals only (1862–66), 26·3 days.
French in infirmary, 12 days.
French *a la chambre*, 3·10 days.
Prussian, (1859–63) in hospitals, 18·9 days.
Belgian, 23·6 days.
Portuguese, 19 days.

(*a.*) *Mortality to Sickness.*—This is, of course, a different point from that of the relation of mortality to strength. A few cases of very fatal illness may give a large mortality to cases of sickness, but the mortality to strength may be very small.

The mere statement of the ratio of mortality to sickness gives little information; what is wanted is the mortality of each disease, and at every age. Otherwise the introduction of a number of trifling cases of disease may completely mask the real facts.

When, however, the general ratio is to be determined, it must be calculated in one of three ways:—

1. Mortality to admissions in the time. This is, however, an uncertain plan; a number of cases admitted towards the close of a period, and the greater part of whose treatment and mortality falls into the next period, may cause an error.

2. Mortality to cases treated (= mean of admissions and discharges).* This is the best method of calculation.

3. Mortality to sick population, *i.e.*, the number of deaths furnished per annum by a daily constant number of sick. This, however, must be taken in connection with the absolute number of sick in the time, and with the duration of the cases, or, in other words, with the kind of cases.

The degree of mortality to the several causes of sickness is given very fully in the Army Statistical Reports, and in a few years some of the most valuable evidence that has ever been given in this direction will be available.

Calculated on the admissions, the mortality to total sickness in the English

* It has not infrequently happened that the mortality on sickness has been calculated in this way; the number of sick remaining in hospital at the commencement of the period, say a year, are added to the admissions in the year, and the mortality is calculated on this number. At the end of the year a certain number of sick remaining in hospital are carried on to the next year, and added to the admissions of that second year for the calculation of the mortality of that year. In this way they are counted twice. This has been done in calculations of weekly mortality, and in this way the same sick man has been made to do duty as a fresh case many times over. This is to be avoided by either calculating on the admissions, or by considering half the "remaining" at the beginning to belong to the previous period, and half the "remaining" at the end of the period to belong to the following period; or, what is the same thing, taking half the admissions and half the discharges in the period as representing the "cases treated" in that time.

army at home is nearly the same as the mortality to strength, or about 9·5 per 1000 per annum. In the Prussian army it is 7·25 (years 1846–62).

Causes of Sickness.

The causes leading men to go into hospital are, of course, very different from those which produce mortality. For example, admissions from phthisis will be few, mortality great; admissions from skin diseases numerous, mortality trifling.

Taking the most common causes of admission in the order of frequency, we find—

1. *Enthetic or Venereal Diseases.*—Under the term enthetic, all diseases, immediate or remote, resulting from sexual intercourse, are included. Secondary as well as primary syphilis; stricture and orchitis, as well as gonorrhœa, &c.; also a few cases not strictly venereal.

In the years 1860–65 the admissions from this class of cases were 325 per 1000 of strength; in 1866 it was only 258, the reduction being chiefly in the class of syphilitic disease. This reduction has not, however, been maintained in the last two years. About 18 men were constantly sick with venereal per 1000 of strength in the former period, and 16 in the latter. (The loss of service to the whole force was nearly 6 days (5·91) per head in 1866.)

In some corps the admissions have been as low as 120 (Household Cavalry), in others as high as 511 per 1000 of strength (Artillery Depôts).

How many of these cases are of infecting syphilis, how many are non-infecting sores, is doubtful; but Dr Balfour has calculated that about 60 per cent. is syphilitic (recent or remote) and 40 gonorrhœal. It varies, however, from year to year (see p. 502).

We have no certain facts with which we can compare the syphilitic disease of the civil population with the enthetic diseases of the army. The amount among the civil population at large is really a matter of conjecture. But whether it is greater or less than that of the army does not affect the result drawn from the above figures, viz., that there is an appalling loss of service every year from the immediate or remote effects of venereal disease.

In foreign armies the evidence is very imperfect. M. Jeannel, in his remarkable book on the prostitution of Bordeaux,* gave a table of cases of venereal (*vénériens*) in the garrison hospitals of thirty French and Belgian garrisons, from which the following is an abstract. The rule in the French service is to send all bad cases from the regimental hospitals to the garrison (the French regimental hospitals are intended only for the treatment of the slight cases of sickness), but yet some slight cases of venereal disease are treated in the infirmaries. This lessens the value of his table, from which the following table is an extract.†

In Brussels the average admissions per 1000 of strength were 89·1 (years 1858–59–60).

In Lille during the same year it was 104·2.

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* Sur la Prostitution Publique, par le Dr J. Jeannel, Pharmacien principal de première classe à l'Hôpital Militaire, &c., Paris, 1862, pp. 196 and 214.

† The rule in the French army about the plan of treatment of venereal disease appears to be this. The Ordonnance of 1839 ordered that slight syphilis requiring local treatment only should be treated in the infirmaries, but that severer cases should be sent to hospital. An order of 1860 (Didiot, *Code Sanitaire*, 1863, p. 204) directs that in any place where there is no (general) hospital, every form of syphilis is to be treated in the infirmaries, under the express condition that the place allows the police surveillance to which these patients are subjected to be carried out. If this cannot be done, the Ordonnance of 1839 is adhered to, viz., that cases requiring local treatment only are kept in the infirmaries.

Number Admitted per 1000 *of Strength in some of the Principal Garrisons, and Average Number of Days of Sickness* (*Jeannel*).

Garrisons.	1858.		1859.		1860.	
	Admissions per 1000 of strength.	Days in hospital for each case.	Admissions per 1000 of strength.	Days in hospital for each case.	Admissions per 1000 of strength.	Days in hospital for each case.
Paris, . .	34·2	29·1	51·1	18·5	33	27
Briançon, .	28·8	34·1	49·3	30·5	19·9	56·7
Montpellier,	52·9	50·5	11·3	46	71	52·6
Toulouse, .	90·4	47·3	83·4	55·6	81·6	37·1
Marseilles, .	113·3	40·2	...	...	127·8	32·6
Calais, . .	132·5	25	60·9	29·3	73·8	30·2
Lyons, . .	136	49·9	165·5	33·6	163	42·2
Nancy, . .	...	...	159·6	33·9	598·1	18·1
Bordeaux, .	255·4	29·4	158·2	27·5	103·5	29·1

In Russia, the admissions from syphilis are about 55 per 1000 (in Europe).

It is not easy to be certain of the comparison between our own and the French army. The French Report for 1866 states that the total admissions for venereal disease in that year were 79 per 1000 of "effective," which would be rather more per 1000 of "present."* Out of every 1000 admissions (to chambers, infirmaries, or hospitals), 53 were venereal, or $\frac{1}{20}$th of the admissions.

This would show an astonishing difference between the two armies, for in ours nearly ⅓d of the admissions are "enthetic." But more precise data are necessary for comparison between the two armies. It is, however, certain that at present our army is suffering more than any other in Europe from venereal diseases.

The comparison between our own and other armies will not affect the fact as regards us—viz., that there is an enormous loss to the State from venereal diseases, and it is urgently necessary that some steps should be taken to lessen the evil (see Prevention of Disease.) It should be understood, also, that the action of syphilis is long continued. Many soldiers die at Netley† from various diseases, whose real affection has been syphilis, so that the influence of this cause is very imperfectly indicated by the number of admissions and service lost under the head of enthetic diseases.

2. *Miasmatic Diseases.*—The important diseases included under this class give one-sixth of the total admissions, or about 170.

The number has been declining during the last eight years.

(*a.*) Eruptive fevers are not very common, about 3 per 1000. Smallpox is checked by vaccination ; measles and scarlatina are not frequent.

(*b.*) Paroxysmal fevers (many of which have been contracted out of England), give about 11 per 1000.

(*c.*) The continued fevers are more common, but their frequency is lessen-

* The "effective" includes the men on furlough, the "present" only those with the colours.

† My colleagues, Professors Maclean and Aitken, are both very much impressed with the frequent occurrence of marks of continued and dominant syphilitic action in the bodies of men who die from what are considered other diseases.

ing. There is no doubt that typhoid is the chief, perhaps almost the only fever besides febricula which is now seen. Spotted typhus is at present very uncommon. The continued fevers cause about 22 admissions per 1000 of strength. In 1866 there was only 15 admissions per 1000. During the last two years there have been a few cases of cerebro-spinal meningitis.

(*d.*) Rheumatism gives 50, dysentery and diarrhœa 25, sore throat and influenza 50, and ophthalmia 20 to 25 cases per 1000 of strength. All these diseases are declining in frequency.

3. Integumentary diseases usually give the next greatest number of admissions—viz., from 100 to 130. This does not include scabies, but is made up of a great number of cases returned as phlegmon and ulcers (which appear to be rather more common among the cavalry and artillery), and a much smaller number of cases of eczema, herpes, psoriasis, and impetigo.

4. Diseases of the respiratory organs (excluding tuberculosis) give the next largest number—viz., from 75 to 110 per 1000, the mean being nearly 100. Of the 100 cases acute bronchitis gives 66·5 per cent.; chronic bronchitis 16·5; and penumonia and pleurisy each 8·5 per cent. (nearly).

5. Accidents follow with from 70 to 80 admissions per 1000 of strength. Contusions are much more common in some regiments than in others, especially in the artillery and cavalry depôts, where recruits are in training.

6. Diseases of the digestive system cause from 35 to 50 admissions; dyspepsia is the chief heading; then chronic hepatitis (although it is very questionable if this term is not a conventionalism), and hæmorrhoids.

7. Parasitic diseases come next, with an average of about 30 or 40 cases per 1000; which are made up of scabies, and a smaller amount of "porrigo."

8. Diseases of the nervous system give about 15 to 20 per 1000. Epilepsy gives the largest number; then otitis; then cephalœa.

9. Tubercular diseases cause about 18 admissions per 1000.

10. Diseases of the reproductive (venereal excluded), locomotive, and urinary, give 6, 3½, and 3 admissions per 1000 of strength.

11. The remaining admissions are made up of smaller classes.

Can the causes of any of these admissions into hospital be lessened or removed? On this point there is no room for doubt that the enthetic admissions could be greatly lessened; so also could the admissions from fever, which have in fact been already reduced from 60 to 22 per 1000 of strength. The large class of integumentary diseases would probably admit of reduction. What is the exact nature of the phlegmon and ulcers which form so large a proportion of the admissions? Trifling as the cases are, they form a large aggregate, and a careful study of their mode of production might show how they might be diminished. Probably, however, these are mere conventional terms, under which a number of trifling cases are conveniently recorded, but a complete analysis of the returns of one year under phlegmon would be desirable. So also of all the other classes, it may be concluded that an active medical officer might succeed in reducing the cases of rheumatism, bronchitis, and dyspepsia.* Many cases of acute respiratory diseases are produced by exposure on guard, especially by the passage into and from the hot close air of the guard-room to the open air on sentry duty. Good additional overcoats, means of drying the clothes, and proper ventilation of the guard-rooms, would probably lessen the cases of bronchitis and pleurisy.

Sickness in Military Prisons.—The admissions into hospital in the military

* It is right, however, to say that no medical officer ought to sacrifice his men in the slightest degree for the purpose of appearing to have a small sick list and an empty hospital. There is a temptation in that direction which we have to guard against, and to remember that the only question to be asked is, What is best for the men? not, What will make the best appearance?

prisons do not appear to be great; they have varied per 1000 of admissions of prisoners from 316 (in 1851) to 725·5 in 1863.* Calculated in the mean strength, the result is as follows :—In 1863, the daily average number of prisoners were 1064; the admissions for sickness, 772; the mean daily sick, 21; the mortality, 0. These numbers give 725·5 admissions, and 19·74 mean daily sick per 1000 of strength. Prisoners are healthier than their comrades at duty in the same garrisons where the prisoners are under sentence.

SECTION III.

Such, then, being the amount of mortality and sickness at home, it may be concluded that the soldier at present is not yet in so good a condition of physical health as he might be; and we can confidently look to future years as likely to show a continuance in the improvement now going on.

Health is so inextricably blended with all actions of the body and mind, that the medical officers must consider not only all physical but all mental and moral causes acting on the men under their charge.

The amount of work, the time it occupies, its relation to the quantity of food, the degree of exhaustion it produces, the number of nights in bed, and other points of the like kind; the mental influences interesting the soldier, or depressing him from *ennui;* the moral effect of cheerfulness, hope, discontent, and despondency upon his health, as well as the supply of water, air, food, clothing, &c., must be taken into account. And just as the body is ministered to in all these ways, so should there be ministration of the mind. It is but a partial view which looks only to the body in seeking to improve health; the moral conditions are not less important; without contentment, satisfaction, cheerfulness, and hope, there is no health.

Hygiene, indeed, should aim at something more than bodily health, and should indicate how the mental and moral qualities, essential to the particular calling of the man, can be best developed.

How is a soldier to be made not merely healthy and vigorous, but courageous, hopeful, and enduring? How, in fact, can we best cultivate those martial qualities which fit him to endure the hardships, vicissitudes, and dangers of a career so chequered and perilous?

Without attempting to analyse the complex quality called courage, a quality arising from a sense of duty, or love of emulation, or fear of shame, or from physical hardihood, springing from familiarity with and contempt of danger, it may well be believed that it is capable of being lessened or increased. In modern armies, there is not only little attempt to cultivate courage and self-reliance, but the custom of acting together in masses, and of dependence on others, actually lessens this. It is, then, a problem of great interest to the soldier, to know what mental, moral, and physical means must be used to strengthen the martial qualities of boldness and fortitude.

The English army has never been accused of want of courage, and the idea of pusillanimity would seem impossible to the race. But drunkenness and debauchery strike at the very roots of courage; and no army ever showed the highest amount of martial qualities when it permitted these two vices to prevail.† In the army of Marlborough, the best governed army we ever had,

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* Report on Prisons for 1863, p. 24.

† There are many sober and excellent men in the army. But as a rule, the English soldier cannot be depended upon under any circumstance, if he can get drink. Well does Sir Ranald Martin say, "Before that terrible vice can be overcome, something far more powerful than medical reasoning on facts, or the warnings of experience founded on them, must be brought

and the most uniformly successful, we are told that the "sot and the drunkard were the objects of scorn." To make an army perfectly brave, it must be made temperate and chaste.

Good health and physical strength, by increasing self-confidence, increase courage; and self-reliance is the consequence of feeling that, under all circumstances, we can face with strength the dangers and difficulties that present themselves.

Few wiser words were ever written than those by William Fergusson,* at the close of his long and eventful service.

"Of the soldier's life within these barracks," writes Fergusson, "there is much to be said, and much to be amended. To take his guards, to cleanse his arms, and attend parade, seems to comprehend the sum total of his existence; amusement, instruction beyond the drill, military labour, and extension of exercises, would appear, until very recently, to be unthought of; as it is impossible that the above duties can fully occupy his time, the irksomeness of idleness, that most intolerable of all miseries, must soon overtake him, and he will be driven to the canteen or the gin-shop for relief.

"Labour in every shape seems to have been strictly interdicted to the soldier, as water for his drink. All, or nearly all, must have been bred to some trade or other before they became soldiers; but they are to work at them no longer. Labour (the labour of field-works and fortifications) strengthens the limbs and hardens the constitution, but that is never thought of in our military life at home; so thought not the ancient Romans, whose military highways still exist, and who never permitted their soldiers to grow enervated in idleness during peace. Better, surely, would it be that every one should work at his own craft, or be employed on the public works, in regulated wholesome labour, than thus to spend his time in sloth and drunkenness.

"But his exercises, without even going beyond the barrack premises, may be made manifold—running, wrestling, gymnastic games of every kind, swimming, leaping, pitching the bar, the sword exercise (that of the artillery), all that hardens the muscles and strengthens the limbs, should be encouraged; and when the weather forbids out-door pastimes, the healthy exercise of single-stick, in giving balance and power to the body, quickness to the eye, and vigour to the arm, may properly be taken as a substitute for the drill which, after the soldier has been perfected in his exercise, is always felt to be a punishment. So is the unmeaning evening parade and perpetual roll-calling. . . . . A couple of guns, even if wooden ones, in every barrack-yard, with an old invalid bombardier to teach the use of the rammer, and the sponge, and the match, would fill up many a dreary hour, and open his mind to a most useful professional lesson.

"Foot-racing too, the art of running, so little practised, and so supremely useful, should be held amongst the qualities that constitute military excellence. It was so held at the Isthmian games of ancient Greece, and deserves a better place than has hitherto been assigned to it in the military pastimes of modern Britain. In our school-books we are told that the youth of ancient Persia were taught to launch the javelin, to ride the war-horse, and to speak the truth. Let the young British warrior be taught to use his limbs, to fire ball-cartridge, to cook his provisions, and to *drink water*. The tuition may be less classical, but it will stand him in far better stead during every service, whether at home or abroad.

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into active operation. Discipline must still further alter its direction;—in place of being active only to punish wrong, it ought and must be exerted further and further in the encouragement to good conduct."—*Ranald Martin, "Tropical Climates,"* p. 263.

* Notes and Recollections of a Professional Life, 1846, p. 49.

"Regular bodily pleasurable exercise has been said to be worth a host of physicians for preserving military health; and occupation without distress or fatigue is happiness. The philosopher can make no more of it; and every idle hour is an hour of irksomeness, and every idle man is, and must be, a vicious man, and to a certain extent an unhealthy one; for the mind preys upon the body, and either deranges its functions in a direct manner, or drives the possessor to seek resources incompatible with health."

In many of the foreign stations of the British army, excellent opportunities exist for both occupying the men and developing their spirit. All history teaches us that a hunting race is a martial one. The remarkable fighting qualities of the English, as drawn in Froissart's Chronicles, were owing to the fact that at that time they were "a nation of hunters," and trained from infancy to face dangers alone. In India there are many places where men could not only be allowed to hunt, but where such permission would be the greatest boon to the inhabitants. Yet this is never thought of, because it is imagined it would relax discipline, or would expose the soldier to the sun. But discipline and health are both infinitely more imperilled by the present system, to say nothing of the soldierly qualities which should be cultivated with so much care.

Moral and mental means for increasing health, courage, and self-reliance, must also be adopted.

The English army offers but few incentives to good conduct, and scanty encouragement for the cultivation of martial qualities. Men must have rewards, and feel that earnest endeavour on their part to become in all respects better soldiers is neither overlooked nor unrewarded.

The cultivation of the martial qualities of the soldier is in reality a part of hygiene considered in its largest sense, but this part of hygiene must be studied and carried into effect by the combatant officers. Let us trust it may not be long before they seriously study and endeavour, by precept and example, to promote the formation of those habits of boldness and endurance, and that fertility in resources, which alone can render an army the formidable instrument it is capable of becoming.

CHAPTER III.

FOREIGN SERVICE.

The foreign service of the British army is performed in every part of the world, and in almost every latitude, and probably more than two-thirds of each line-soldier's service is passed abroad. The mere enumeration of the stations is a long task; the description of them would demand a large volume. In this short chapter, to give a few general statements as to climate and geology, and the past and present medical history of the stations, only can be attempted; such an outline as may give medical officers a sort of brief summary of what seems most important to be known.

Detailed and excellent accounts of most of the foreign stations exist, either in the independent works of army surgeons, such as those of Marshall, Hennen, Davy, and many others, or in reports drawn up for Government, and published by them. In the early Statistical Reports of the Medical Department of the army, short topographical notices of the stations were inserted; they are models of what such reports should be, and must have been drawn up by a master in the art of condensation. In the Annual Reports now published, many excellent topographical descriptions will be found; and some of the Indian Governments have published complete descriptions of all their stations. In the "Bombay Transactions," the "Madras Medical Journal," and the "Bengal Indian Annals," are very full accounts of almost every station that has been, or is, occupied by European troops in India. Finally, in the "Indian Sanitary Report" is much important information on the meteorology and topography of the present Indian stations. Young medical officers first entering on foreign service are strongly advised to study these accounts of the stations in the command where they are serving; it will not only give them interest in their service, but will aid them in their search how best to meet the climatic or sanitary conditions which affect the health of the men under their charge.

SECTION I.

MEDITERRANEAN STATIONS.*

Gibraltar.

Usual peace garrison = 4500 to 6000 men. Period of service, three years. Civil population = 17,750 (in 1857). Height of rock, 1439 feet at highest point. Nature of rock, grey limestone, with many cavities filled with reddish clay; under town, an absorbent red earth forms the subsoil.

* A very important Report on the Mediterranean Stations has been published by the Barrack Improvement Commissioners (Dr Sutherland and Captain Galton).—*Blue-Book*, 1863.

Climate.—Mean temperature of year = 64·1 ;* hottest month, August (invariably in eight years) = 76·6 ; coldest month, either January or February, in equal proportions, 53·77 ; amplitude of the yearly fluctuation, 22·83 (= difference between hottest and coldest months).

Mean monthly maximum and minimum in shade †—Hottest month, July or August—mean maximum = 89 ; coldest month, December, January, or February—mean minimum, 42°. Range of highest and lowest monthly means of maximum and minimum, 47°. Extreme yearly range (difference between highest and lowest temperature recorded in the time) about 50° to 58°. The minimum thermometer on grass sometimes falls to 4° or 6° below freezing.

Rainfall.—Mean 32·8 inches (mean of seventy years, 1790–1860). Greatest amount in any one year, 75·8 (1855). Least amount in any one year, 15·1 (1800). The importance of this great variation, as regards sieges, is evident; Gibraltar might be embarrassed for water, if the rain-fall were only 15 inches in a year of siege.

Number of Rainy Days = 68. The rain is therefore infrequent, but heavy. The rain falls in nine months, September to May; greatest amount in January and November ; most rainy days in April. Summer, rainless.

Humidity.

	Dew-point.	Grains of Vapour in a cubic foot.	Relative Humidity Sat. = 100.
Mean dew-point of year, .	55°·9	5·75	72·3
Mean highest dew-point in August, . . .	67°·9	7·5	70·9
Lowest dew-point in January or February, . .	43°·5	3·25	69·1

Gibraltar is thus seen to be rather a dry climate ; at any rate, the air is on an average only three parts saturated with moisture, and therefore evaporation from the skin and lungs will be tolerably rapid, provided the air moves freely. It is certainly not a moist insular climate, as might have been anticipated. At the times of rain, however, and during the fogs and moist sirocco, the air is nearly saturated.

Winds.—Chiefly to the N.W. or S.W. or W., in January, April, May, June, and October. Easterly in July, August, and September. But sometimes the easterly winds are more prevalent, or may be moderate for almost the whole year. The east and south-east winds are sirocco (Levanteros), and are often accompanied by rain and fogs.

Sanitary Conditions.

Water Supply.—The *quantity* has been very deficient; in 1861 only 2½ gallons daily were supplied for non-commissioned officers and privates.

Sources.—Wells and tanks, rain water, and a small aqueduct carrying surface water. Lately very large tanks have been constructed in two of the ravines, with arrangements for passing into them a large amount of surface water. This will add largely to the storage.

Quality.—In a well from the neutral ground analysed by Mr Abel, there

* Mean of eight years' observations by the Royal Engineers (1853–1860), as given in the Barrack Commissioners' Blue-Book (1863). The numbers given by Dove are rather different, viz., mean of year 66°. Hottest month, July, 79°·5. Coldest month, February, 56°·6. Mean yearly range, 22°·9. Extreme yearly range, about 50°.

† Of the eight years (1853–60) given in the report above quoted, the difference between the monthly mean maximum and minimum is so much less in the last three years, as to make one suspect some error in observation.

was much calcium sulphate and nitrate (4·5 and 6 grains per gallon), and calcium carbonate (12 grains per gallon), also alkaline chlorides (7 or 8 grains), and 4 grains of organic matter. A tank water contained less lime, but much magnesium carbonate. A well water in the town contained no less than 39·6 grains of calcium nitrate, and 15 grains of calcium sulphate, per gallon. The immense amount of nitric acid points unequivocally to the oxidation of animal organic matter. The tank water is good when filtered; but the tanks require frequent inspection and cleaning.

Many of the houses of the civilians have tanks, and no new house is allowed to be built without a tank. The distribution of water, both to soldiers and civilians, is defective; it is almost entirely by hand.

Drainage.—The sewers are at present being much improved. A new outfall near Rosina Bay has been made, and the whole system of sewage will soon be in fair order.

Barracks.—More than half the garrison is in casemates, which are "mere receptacles of foul air, damp, dark, and unwholesome." * The barracks are, for the most part, badly arranged, and are overcrowded; the average cubic space in 1862 was only about 450 feet, and the average superficial space under 40. Ventilation was very defective, especially in the casemates. In all those points, however, improvement has taken place. The means of ablution are defective. Latrines and urinals are also defective.† The duties are not heavy, and the rations are said to be good. In 1860 some improvements were made in the dress of the troops, and a light summer suit ordered. Flannel next the skin has been recommended strongly for Gibraltar, on account of the occasional cold winds.

Health of the Civil Population.

Gibraltar is now a place of considerable trade; whether the Government have been right in allowing a mass of people to herd closely together in the midst of the most important fortress we possess, is very questionable. In case of a siege they would be a serious embarrassment, and even in time of peace they are objectionable. The health of this community is bad; in 1860, the northern district, where population is densest, gave 38 deaths per 1000, or, excluding cholera, 33·5; in the more thinly populated southern end, the mortality was 27·5 per 1000, or more than St Giles', in London. The deaths in children under one year form 17·33 per cent. of the total mortality. The prevailing causes of this mortality are fevers (in all probability typhoid), and tuberculous consumption, which causes 13 per cent. of the total deaths at all ages, or 37·6 per cent. of the total deaths at the soldiers' ages. Dysentery and diarrhœa are common.

In this compressed and dirty population several great epidemics have occurred. The bubo plague has not been seen since 1649; but yellow fever prevailed in 1804, 1810, 1813, and 1828. Cholera has prevailed several times; the last time was in 1865.

Health of the Troops.

Loss of Strength by Death and Invaliding.

(*a.*) *By Death.*—Gibraltar has never suffered from any great sickness or

* Barrack Commissioners' Report, p. 37.

† All these points are noted in the Barrack Commissioners' Report, and are in process of alteration; they are merely referred to here as bearing on the question of the amount and prevention of disease. Plans of all the proposed improvements are given in the Commissioners' Report.

mortality, except in yellow fever or cholera years. At the time when the mortality in home service was 17 or 18 per 1000 of strength, it was usually not more than 12 at Gibraltar. Of late years both sickness and mortality has been below that of home service, especially in the latter years. In spite of this comparative healthiness, it is quite certain that much preventible disease existed, and in part still exists on the Rock.

Mortality per 1000 *of Strength.*

Years.	Total Deaths.	Deaths from Disease alone.
1837–46 (10 years), ...	12·9	
1859–65 (7 years),*	9·78	8·87
1866 (1 year), ...	4·36	4·14
1867 (1 year), ...	7·69	6·81

I have placed the two last years by themselves to show what low mortality is possible among soldiers, and what in all probability may be the usual amount in future years.†

Causes of Death.—In the earlier years the chief causes of death were phthisis and continued fever, which was doubtless enteric fever. Of late years phthisis has declined; enteric fever, on the contrary, increased up to 1863, has since then declined in frequency, though not in fatality per cent. of attacked. By expressing the facts as per cent. of deaths, the relation will be seen clearly—

In 100 *Deaths from all Causes.*

Years.	Phthisis.	Continued (Enteric Fever chiefly).	Head Affections, Delirium Tremens included.
1837–46, ...	41	17·65	9·28
1863–66, ...	16·84	28·94	
1867, ...	22·75	11·44	

Instead of expressing the facts in this way, they may be put in another form. The admissions from phthisis averaged 11 per 1000 of strength in the ten years, 1837–46, while in the eight years, 1859–66, they were only 7·63. In the years 1863–66 the deaths and invaliding together from phthisis were only 3·72 per 1000 of strength, or hardly more than the deaths alone at home. The decline in phthisis seems therefore certain; and still it is possible that it is not even now so low as it might be.

The continued fevers gave 75·5 admissions per 1000 of strength in the years 1837–46, and 98·5 in the five years ending 1863. There was also an increase in mortality. In the three years ending 1866 the admissions fell to an average of 42, and the decline was progressive. In 1867 there was an increase in admissions, owing to the prevalence of a mild fever very like the dengue of the West Indies. The mortality has not declined *pari passu*, and therefore the lessening has been in slight cases.

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* Cholera prevailed in 1865, and raised the mortality to 23·74. Without cholera it was 7·91.

† Of course invaliding has an effect, but the invalids who died at Netley are included in the above numbers.

Even this mortality is more than is necessary. In 1866 there were 15 deaths out of 4585 men men. Of these, 3 from typhoid, and therefore preventible, 4 from phthisis, 2 from apoplexy, 3 from heart disease, 1 from aortic aneurism, 1 from asthma, and 1 from violence. The immense relative amount of disease of the circulatory organs is striking; it formed 26·6 per cent of total deaths; and in each of the three preceding years there had been 3 deaths under the same headings.

During these last three or four years especially, much has been done in Gibraltar to give the men more breathing space and ventilation, hence the decline in phthisis which was so fatal formerly when the men were crowded in casemates. When their barracks are still further improved, we shall see a still greater lessening of phthisis.

During the last three or four years the water supply has been better looked after, and efficient drainage has been commenced, and is now almost completed. I believe the effects can be seen even in the years 1865, 1866, and 1867; and I anticipate that when the returns of succeeding years come to be published, a still greater improvement will be found to have taken place.

The prevalence of heart diseases is a striking circumstance, and I cannot but believe is caused by the same conditions as at home.

The habits of the men are much improved, and delirium tremens, formerly common, is rare. In 1865 and 1866 only one man died in two years from this cause, or at the rate of scarcely more than ·1 per 1000 of strength.

Formerly dysentery and diarrhœa were common; now they are infrequent and mild. The average admissions from dysentery in three years (1864–66) were only 2 per 1000; in 1864 and 1866, from diarrhœa, were only 12 per 1000.*

Everything points to the fact that Gibraltar itself is a perfectly healthy place, and, that when the sanitary alterations now going on are completed, the sickness and mortality will be trifling.

(*b.*) *By Invaliding.*—The number of men sent home for change of air and discharge varies greatly from year to year; about 20 to 30 per 1000 of strength is the average. The chief diseases are ophthalmia, phthisis, syphilis, and cardiac disease. The other diseases are in smaller number, but are numerous. Dysentery and liver diseases used to be common causes of invaliding, but both are now declining.

2. *Loss of Service by Sickness.*

The admissions, the mean daily sick, and the duration of the cases, are all below the home standard.

Per 1000 *of Strength.*

Years.	Admissions per Annum.	Mean daily Sick.	Mean Stay in Hospital of each Sick Man in days.
1837–56, .	976	...	...
1859–65, .	821·3	41·34	18·37
1866, . .	587·1	33·37	20·74
1867, . .	709·9	34·91	17·94

The venereal diseases cause fewer admissions than at home; the average of the whole enthetic class is only about 170 per 1000. This is owing to the police regulation of prostitutes. Integumentary diseases cause, as at home, the next largest admissions; about 100 per 1000. "Continued fevers" in years gone by usually took the third place, but they are now loosing that bad eminence. Dysentery and diarrhœa are now declining from the former average of 58 to 20 or 30 per 1000. Digestive disorders give a large number of admissions, and have always done so, but in the latest returns they are also

* Cholera prevailed in 1865, so I have left that year out.

declining. Everything seems, then, to show a gradually improving condition of things at Gibraltar.

Sanitary Duties at Gibraltar.—Captain Galton and Dr Sutherland have already indicated the measures which must be adopted, viz., a better supply of water, by arranging a larger storage; a better drainage, with sea-water for flushing, and a different outlet; and an improved ventilation, with less crowding in barracks. All the plans are being gradually carried out. There is no doubt these measures will greatly improve health.

It may be suggested whether, as water is so deficient, a removal of sewage by hand might not be employed. The soil might be used for cultivation in the neighbourhood of the Rock, or carried out to sea.

Supposing war were to arise at this moment, and that we lost the command of the sea for a time, the points of danger would apparently be these:—

1. *Deficient Water, the Rainfall being uncertain.*—This would have to be supplied by distillation, and it would be prudent to keep a good apparatus always at Gibraltar. The amount of storage has been increased of late years.

2. *Overcrowding and Bad Ventilation, leading to Spotted Typhus.*—With a full garrison, and with some barracks untenable, there is no doubt there would be serious danger of this disease; and it is a matter of great moment to ventilate as perfectly as possible all casemates which, even if now disused, must be used in time of war.

3. *Typhoid Fever.*—The drainage is now being improved, so that this cause of danger may soon be entirely removed.

4. *Diseases arising in the Town, and spreading to the Garrison.*—In case of war, it would seem most desirable to clear out the native town as far as it can be done. More space and more water would be available. There would be less chance of famine, destitution, and disease.

In the war in 1782, scurvy prevailed from deficiency of food and fresh vegetables.

Malta.

Size, 17 miles by 8. Usual peace garrison = 6000 to 7000; period of service, three years; population (civil) in 1851 = 98,021.

Geology.—Soft, porous rock; the greater part is sandstone resting on hard limestone; in some parts there is marl and coral limestone over the sandstone. In the centre of the island, at Citta-Vecchia, there is, in order from the surface, alluvium, upper limestone, red sand, marl, sandstone, and lower limestone. Valetta is on thin alluvium, with thick sandstone below, and beneath this the lower limestone.

Climate (at Valetta).—Mean of year, 68°; hottest month (July), 77°; coldest (January), 57°; amplitude of the yearly fluctuation, 20°; extreme yearly range (from highest to lowest temperature in shade), 62°, from 100° in July to 39° in January; mean yearly range, about 50°; extreme monthly range (*i.e.*, from highest to lowest in month), about 25° to 35°.

Undulations of temperature are frequent, and there are often cold winds in winter from N.W. The south-east wind is an oppressive sirocco, raising the temperature to 94° or 95°. It is chiefly in the autumn, and blows for from 60 to 80 days every year. At Citta-Vecchia (600 feet above the sea) the temperature is lower and the air keener. Rainfall about 32 inches. Chief rain in November, December, and January; less in February and March; small in amount in the other months. From June to August almost rainless.

Humidity.—(Mean of 1859–60); observations at 9.30 A.M. and 3.30 P.M.

	Dew-point.	Grains of Vapour in a cubic foot.	Relative Humidity.
Mean of year, . . .	60·5	5·87	62
Highest in year (August), .	72·7	8·73	...
Lowest in year (February),	49	3·96	...

Malta thus appears to be a dry climate, *i.e.*, with little relative humidity.

Sanitary Condition.

Much has been done of late years, and, as far as external cleanliness goes, Valetta is very clean. Water supply from rain and springs (the largest of which is in the centre of the island, and the waters of which are led by aqueduct), is not very deficient in quantity (8 to 10 gallons per head), and, except in some places, good in quality, though the rain-water contains chlorides from the spray falling on the roofs of buildings. Some of the tanks are too near the sea, which percolates into them. The tanks require, however, careful looking after. Within the lines there are 272 public and military tanks, with storage for 55 millions of gallons, and 4294 private tanks, with storage for 323 millions of gallons. The military tanks, if full, would give 6 gallons of water per man daily for eleven months, but even now the water often falls short. The water is now carried everywhere by hand, and the drinking-water for the men is not filtered. An attempt to get water by sinking into the sandstone was made in 1866–67, but failed. The sewers in Valetta are bad in construction and outlet, and much typhoid has been, and is still, caused in consequence. In many cases "they are nothing but long cesspools."* Pipe drains are, however, now being laid in the old drains, which were merely narrow deep channels cut in the soft porous rock.

The barracks are bad, many casemates being used, and buildings intended for stores and not for habitations. In some cases, all sanitary considerations have been sacrificed for the purposes of defence. They are built of soft sandstone, which both crumbles and absorbs wet. The ventilation of the casemates is very bad. The Barrack Commissioners, in their Report, recommended that in every way which can be done the ventilation should be improved by admitting the wind, especially from the north, and that each barrack will require a separate plan to meet the particular case. They recommend that air shafts shall be made, much larger than ordered for home service, viz., 1 square inch for every 20 cubic feet of space, or for a barrack of twelve men with regulation space $(7200 \times 20 =)$ 360 square inches $(= 2\frac{1}{2}$ square feet) of outlet opening. At the present time the amount of cubic space is below the home service amount (600 cubic feet), and the superfical area is very small, one-fourth of the men having less than 40 square feet each.

Means for ablution are very deficient. Urinals and water latrines are made of porous stone, and are also bad in construction.

It is therefore evident that the same diseases may be expected at Malta as formerly prevailed at Gibraltar, viz., typhoid fever from bad drainage, and lung disease from the faulty ventilation. As the water is less impure than formerly, the amount of dysentery may be expected to be less.

Health of the Civil Population.

There is some, but no great amount, of malarious disease, but a good deal

* Barrack Commissioners' Report, p. 111.

of the so-called bilious remittent,* and typhoid. Typhus is not at present seen. Bubo plague has prevailed seven times, the last in 1841, slightly. Yellow fever has been known, but not of late years. Cholera has occurred thrice. Dysentery is common; tænia not infrequent; ophthalmia common, from dust and glare. Boils or anthrax are frequent; rheumatism is not uncommon, and phthisis is said to be frequent (from dust?). The death rate is said to be 21·3 per 1000 in the towns, and 28·7 in the country districts; while nearly 57½ per cent. of this is in children under five years,† the great causes of infantile mortality being registered as teething and convulsions.

Health of the Troops.

On the whole, the health of the troops is worse than at Gibraltar, but it has singularly fluctuated (even without great epidemics), more so probably than at any station in the same latitude. The mortality has varied as much as threefold without cholera.

Years.	Loss of Strength per 1000 per annum.			Loss of Service per 1000 per annum.		
	Total Deaths.	Deaths from Disease.	Invaliding.	Admissions.	Mean daily Sick.	Days in Hospital to each Sick Man.
1837–46, . .	15·3	...	...	1120	43·79	...
1859–65, . .	12·72	11·3	19	882·8	45·96	19·36
1866, . . .	12·88	10·92	16·5	922·3	48·83	19
1867, . . .	24·19	20·93	26·8	863·4	46·76	19·77
Highest in 1865 (cholera)	26·44	24·63	...	...	...	...
Lowest in 1864,	6·53	4·58	...	...	...	...

The mortality in 1864 was as low as it has ever been; but it has in former years been as low as 5·6. It is curious how altenations of health and sickness occur chiefly from the variations in the fevers of different kinds, especially enteric (typhoid), and the remittent or so-called Malta fever, which has a long course, a great tendency to rheumatic sequels, and little mortality.

In 1867 there was a terrible outbreak of continued fever, chiefly among the troops quartered in the notoriously unhealthy barracks of Lower St Elmo and Fort Ricasoli. The admissions rose to 228, and the deaths actually amounted to no less than 7·93 per 1000 of strength. Out of 100 deaths no less than 32·2, or nearly ⅓d, were from "continued fever," *i.e.*, enteric fever in great measure.

In former years phthisis was the cause of 39 per cent. of the deaths, or nearly the same as at Gibraltar. Latterly there have been fewer deaths at Malta, but a considerable number of tubercular cases are sent home. The disease is probably detected more early, and the men do not die as formerly at the station. Still this does not account for the whole diminution, and there has been clearly a lessening of phthisis. There was formerly a large amount of

* See Dr Marston's excellent Report in the Army Medical Report for 1861, for the symptoms of this disease among troops. See also Dr Boileau's interesting essay in the same publication, vol. viii.

† Report of Barrack Commissioners, p. 87. The Commissioners justly remark that these figures are so striking as to demand further inquiry. Probably they are quite untrustworthy; yet both at Gibraltar and Malta it would be of the greatest importance, not merely for the health of the troops in peace, but for the security of the fortress in war, to know everything about the social life and the diseases of the native population.

stomach and bowel disease, and dysentery was forty times as frequent as in England.* It is certainly a very remarkable circumstance, that both at Gibraltar and Malta there should have been this extraordinary liability to affections of the alimentary canal. At Malta, as at Gibraltar, it may have been chiefly owing to impure water and to food (Report of 1853, p. 118). Of late years stomach and bowel affections have been less frequent, but are still more common than at home; in 1861, the 89,000 men on home service gave only 67 cases of acute dysentery and no deaths, while the 6000 men at Malta had 34 cases and 2 deaths. In 1864 there were 3 deaths from acute dysentery among 5654 men, while in the home station there was only 1 death among 73,252 men. If it had been equally fatal at home, there would have been nearly 39 deaths.

A continued fever (which was probably in great measure typhoid) has prevailed more or less for the last forty years at Malta, and doubtless also before that time. It has been quite as prevalent and fatal of late years as formerly; in 1859 there were 1413 admissions out of a garrison of 5310 men, or at the rate of one man in every four; and the deaths from fever were 44 out of 96 total deaths, or 45·83 of the total mortality. In 1863 there were 844 admissions and 21 deaths out of a garrison of 5494 men. This is more than in any town or village in England. In 1864 there were 1057 cases and 6 deaths out of a garrison of 5654 men. In 1865 there were 1162 admissions and 13 deaths out of 5323 men; and in 1866, 1031 admissions and 19 deaths out of 5202 men.

In the Statistical Report for 1853, it is observed that the number of cases of liver disease at Malta are remarkably high; and the writers, while believing there must be "something in the climate of Malta peculiarly favourable to the production of hepatic affections," were unable to find, on bringing the cases into relation with the temperature, any connection. The cause of this may be something very different, and it is very desirable that the food should be looked to. There is a suspicion at Netley (which requires a few years more experience to test it) that the cases of echinococcus of the liver are more frequent in men from the Mediterranean stations than others (Dr Maclean). The case of Iceland should lead us to look into this point. The history of admission for venereal disease is important; in 1837–1846, inclusive, the admissions were only 99 per 1000, or two-thirds less than at home; in 1859, when the next report appeared, they were 149 per 1000; and in 1860 they were 147·9 per 1000. In the early period there were police regulations, which were suspended in the two latter years. In June 1861 the police regulations were re-enforced, and the admission for the year sank to 102. The 4th battalion of the Rifle Brigade showed the following remarkable result:—In the first half of 1861, there were 57 admissions; in the last half, only 17. In 1862, the total number of cases of "enthetic disease" in the whole garrison were only 49·5; in 1863, 44·1, and, in 1864, 53·2 per 1000. They were increased in that year by the women who came from Ionia with the troops. In 1865 they were 44; in 1866, 59·6 per 1000. The result, compared with home service, is marvellous; the reduction is almost entirely of syphilis, not of gonorrhœa. The large number of admissions from phlegmon and ulcers is as striking in Malta as at Gibraltar and at home; and here as there, these are probably mere conventional terms. Such then, in brief, seem to be the chief medical points of importance at Malta, viz., a liability to phthisis, less marked of late years; a great amount

* In England, in 1837–46, every 1130 men gave one case of dysentery; in Malta, in the same years, every twenty-eight men gave one case of dysentery. The mortality of the disease was, however, nearly the same (see pages 21 and 118 of the Report of 1853).

of fever, from bad sanitary conditions in great part; a liability to stomach and intestinal affections, which, though less obvious, is still great, and a singular tendency to a liver affection, which may be parasitic. The chief improvements advised by the Barrack Commissioners refer to a larger water supply, a better distribution, improved drainage, and efficient ventilation.

In time of war, the dangers at Malta would be the same as at Gibraltar; the aqueducts might be cut by a besieging force, and the water supply restricted to the tanks. Although these are supposed to hold a large quantity, they are not kept full, and could not, perhaps, be rapidly filled. The garrison might be driven to distil the sea water. The Barrack Commissioners very properly strongly advise that a tank inspector should be appointed. A still more serious danger would be the overcrowding of a war garrison. Doubtless, in case of a war, the garrison would only be concentrated in the lines when the siege commenced, but the crowding during a siege of three or six months might be very disastrous. This danger should be provided for beforehand by a clear recognition of what accommodation would be wanted for war, and how it is to be obtained without violating either the conditions of health or of defence.

The drainage will no doubt be soon remedied in accordance with the recommendations of the Barrack Commissioners.

SECTION II.

WEST INDIES.

The history of sanitary science affords many striking instances of the removal of disease to an extent almost incredible, but no instance is more wonderful than that of the West Indies. Formerly, service in the West Indies was looked on as almost certain death. It is not fifty years since the usual time for the disappearance of a regiment of 1000 strong was five years. Occasionally in a single year a regiment would lose 300 men, and there occurred from time to time epochs of such fatality that it was a common opinion that some wonderful morbid power, returning in cycles of years—some wave of poison—swept over the devoted islands, as sudden, as unlooked-for, and as destructive, as the hurricanes which so sorely plague the

"Golden isles set in the silver sea."

What gave countenance to this hypothesis was, that sometimes for months, or even for a year together, there would be a period of health so great that a regiment would hardly lose a man. But another fact less noticed was not so consistent with the favourite view. In the very worst years there were some stations where the sickness was trifling; while, more wonderful still, in the worst stations, and in the worst years, there were instances of regiments remaining comparatively healthy, while their neighbours were literally decimated. And there occurred also instances of the soldiers dying by scores, while the health of the civil inhabitants in the immediate vicinity remained as usual.

If anything more were wanted to show the notion of an epidemic cycle to be a mere hypothesis, the recent medical history of the West Indies would prove it. At present this dreaded service has almost lost its terrors. There still occur local attacks of yellow fever, which may cause a great mortality; but for these local causes can be found; and apart from these the stations in the West Indies can now show a degree of salubrity almost equalling, in some cases surpassing, that of the home service.

The causes of the production, and the reasons of the cessation, of this great

mortality are found to be most simple. It is precisely the same lesson which we should grow weary of learning if it were not so vital to us. The simplest conditions were the destructive agents in the West Indies. The years of the cycles of disease were the years of overcrowding, when military exigencies demanded that large garrisons should hold the islands. The sanitary conditions at all times were, without exception, infamous.

There was a great mortality from scorbutic dysentery, which was almost entirely owing to diet.* Up to within a comparatively late date, the troops were fed on salt meat three, and sometimes five, days a week, and the supply of fresh vegetables was scanty. It required all the influence of Lord Howick, the then Secretary at War, to cause fresh meat to be issued, though it had been pointed out by successive races of medical officers that fresh meat was not only more wholesome, but was actually cheaper. The result of an improvement in the diet was marvellous; the scorbutic dysentery at once lessened, and the same amount of mortality from this cause is now never seen. Another cause of dysentery was to be found in the water, which was impure from being drawn from calcareous strata, or was turbid and loaded with sediment. The substitution of rain water has sufficed in some stations to remove the last traces of dysentery.

If the food and water were bad, the air was not less so. Sir Alexander Tulloch has given a picture of a single barrack at Tobago, said to be the "best in the whole Windward and Leeward Command,"† the figures of which tell their own tale.

Barrack at Tobago in 1826.—Superficial space per man, 22½ feet; breadth, 23 inches; cubic space, 250 feet.

The men slept in hammocks, touching each other. In these barracks, crowded as no barracks were even in the coldest climates, there was not a single ventilating opening except the doors and windows; the air was fœtid in the highest degree. With this condition of atmosphere, it is impossible not to bring into connection the extraordinary amount of phthisis which prevailed in the soft and equable climate of the West Indies. There was more phthisis than in England, and far more than in Canada. The first great improvement was made in 1827, when iron bedsteads being introduced, each 3 feet 3 inches wide, greater space was obliged to be given to each man.

Every arrangement for removal of sewage was barbarous, and in every barrack sewage accumulated round the buildings, and was exposed to heat and air. When yellow fever attacked a regiment, every stool and evacuation was thrown into the cesspools common to all the regiment; and in this way the disease was propagated with great rapidity, and was localised in a most singular manner, so that a few hundred yards from a barrack, where men were dying by scores, there would be no case of fever. In spite of this, it was many years before the plan of at once evacuating a barrack where yellow fever prevailed was adopted.

The barracks themselves were usually very badly constructed, and when in some cases the architects had raised the barracks on arches from the ground, in order to insure perflation of air below the buildings, the arches were blocked up or converted into store-rooms; and the barracks, with spaces thus filled with stagnant air beneath them, were more unhealthy than if they had been planted on the ground.

The localities for barracks were often chosen without consideration, or for

* This is pointed out, in the Statistical Report (1838) on the West Indies, by Tulloch and Balfour; and it is believed that the improvement in the diet was in a great measure owing to these gentlemen.

† Report, 1838.

military reasons,* into which no consideration of health entered. Almost all were on the plains, near the mercantile towns, where the soil was most malarious, and the climate hottest and most enervating. Malarious fevers were, therefore, common.

To all these causes of diseases were added the errors of the men themselves. For the officers there existed, in the old slave times, the greatest temptation. A reckless and dangerous hospitality reigned everywhere; the houses of the rich planters were open to all. A man was deemed churlish who did not welcome every comer with a full wine, or more often a brandy, cup.

In a climate where healthy physical exertion was deemed impossible, or was at any rate distasteful, it was held to be indispensable to eat largely to maintain the strength. To take two breakfasts, each a substantial meal, was the usual custom; a heavy late dinner, frequently followed by a supper, succeeded; and to spur the reluctant appetite, glasses of bitters and spirits were taken before meals.

The private soldiers obtained without difficulty abundance of cheap rum, which was often poisoned with lead. Drunkenness was almost universal, and the deaths from delirium tremens were frequent and awfully sudden. The salt meat they were obliged to eat caused a raging thirst, which the rum bottle in reality only aggravated.

To us these numerous causes seem sufficient to account for everything, but in former days an easier explanation was given. It was held to be the climate; and the climate, as in other parts of the world besides the West Indies, became the convenient excuse for pleasurable follies and agreeable vices. In order to do away with the effects of this dreaded climate, some mysterious power of acclimatisation was invoked. The European system required time to get accustomed, it was thought, to these climatic influences, and in order to quicken the process various measures were proposed. At one time it was the custom to bleed the men on the voyage, so that their European blood might be removed, and the fresh blood which was made might be of the kind most germane to the West Indies. At other times an attack of fever (often brought on by reckless drinking and exposure) was considered the grand preservative, and the seasoning fever was looked for with anxiety. The first statistical report of the army swept away all these fancies, and showed conclusively that instead of prolonged residence producing acclimatisation and lessening disease, disease and mortality increased regularly with every year of residence.

The progress of years has given us a different key to all these results. It is now fully recognised that in the West Indies, as elsewhere, the same customs will insure the same results. Apart from malaria, we hold our health and life almost at will. The amount of sickness has immensely decreased; occasionally in some stations which used to be very fatal (as at Trinidad) there has not been a single death in a year among 200 men. Among the measures which have wrought such marvels in the West Indies have been—

* The history of the old St James's Barracks in Trinidad is too remarkable to be passed over. It was determined to build a strong fort—a second Gibraltar—on the lower spurs of the hills overlooking the plain where the barracks now stand. When the works had been carried on for some time, it was discovered that they could not hold the troops. The barracks were then ordered to be placed on the plain, under cover of the guns of the fort. Before the fort was quite finished, it was found to be so unhealthy that neither white nor black men could live there, and it was abandoned. The barrack, it is said, was not then commenced; yet, though the reason for placing it in that spot had gone, it was still built there, on a piece of ground near two marshes (Cocorite and the Great Western Marsh), below the general level of the plain, and exposed to the winds from the gullies of the neighbouring hills. Yet this bad position, so fruitful of disease, was in reality less injurious than the bad local sanitary arrangements of the old St James's Barrack itself.

1. A better supply of food; good fresh meat is now issued, and vegetables, of which there is an abundance everywhere.

2. Better water.

3. More room in barracks, though the amount of cubic space is still small.

4. Removal of some of the stations from the plains to the hills: a measure which has done great good, but which can explain only a portion of the improvement. The proper height to locate troops is by most army surgeons considered to be at some point above 2500 feet.

5. Better sewage arrangements, and more attention generally to sanitary conservancy.

6. A more regular and temperate life, both in eating and drinking, on the part both of officers and men.

7. The occupancy of the unhealthy places, when retained as stations, by black troops.

8. A better dress. It is only, however, within the last few years that a more suitable dress has, at the instance of the late Director-General, Sir J. B. Gibson, been provided for the West India islands.

The army stations in the West Indies are, Jamaica, Barbadoes, Trinidad, St Lucia; the last three being included in the term "Windward and Leeward Command." British Guiana, on the mainland, is part of this command. There are small parties of artillery and some black troops in Honduras and the Bahamas.

The period of service is now three or four years; formerly it was eleven or twelve, but this was altered after the first statistical report. Usually the Mediterranean regiments pass on to the West Indies, and subsequently to Canada.

The proper time for arriving in the West Indies is in the beginning of the cold season, viz., about the beginning of December, when the hurricanes and autumnal rains are usually over.

Jamaica.

Present strength of white garrison, 600 to 700; black troops, 700 to 800. A range of lofty hills (Blue Mountains) divides Jamaica into two parts, connected by a few passes. The troops were formerly stationed chiefly in the south plains, at Kingston, Port-Royal, Spanish Town, Up-Park Camp, Fort-Augusta, &c. After the Maroon war in 1795 some troops were stationed at Maroon Town (2000 feet above the sea) on the north side, and at Montego Bay. Subsequently Stoney Hill (1380 feet above the sea), at the mouth of one of the passes, was occupied.

Since 1842 some, and now nearly all the troops, are at Newcastle, in the hills, 4000 feet above the sea, with detachments at Kingston and Port-Royal. The other stations are now disused for white troops. The sanitary condition at Newcastle was formerly not good; the sewage arrangements were very imperfect; it is now somewhat improved.

Climate.—The climate is very different at the different stations. At Kingston (sea-level)—temperature, mean of year = 78°·0; hottest month, July, mean = 81°·71; coldest month, January, mean = 75°·65; mean yearly fluctuation = 6°·06. Undulations trifling. The climate is limited and equable. At Newcastle the mean annual temperature is about 66°; hottest month, August = 67°·75; coldest month, February = 61°. The diurnal range is considerable, but the annual fluctuation is trifling (about 6°). The mean of the year is therefore much lower than on the plains; the amplitude of the yearly fluctuation about the same; the diurnal change greater.

Humidity.—This is considerable in the plains—often from 80 to 90 per cent. of saturation = 7 to 9 grains of vapour in a cubic foot. At Newcastle the mean yearly dew-point is about 60°; the amount of vapour in a cubic foot of air is 5·77; the mean yearly relative humidity is 68 per cent. of saturation.

Rain.—Amount on the plains = 50 to 60 inches, in spring and autumn, viz., April and May, and October and November. Showers in July and August.

Winds.—Tolerably regular land winds at night, and sea breezes in the hot and dry months during the heat of the day. The central chain of mountains turns the north-east trade wind, so that it reaches the south side diverted from its course; from December to February the wind is often from the north, and brings rain and fogs ("wet northers"). The south-east wind in April and May is very moist. The hurricane months are from the end of July to the beginning of November. The climate in the plains is therefore hot, equable, and humid.

Health of the Black Civil Population.

Of the specific diseases smallpox and the other exanthemata are common. Spotted typhus is said to be unknown; typhoid is said to be uncommon, but is probably more common than is supposed. Influenza has prevailed at times, and also the so-called dandy or polka. Cholera has prevailed severely. Malarious fever is common over the whole of the south plains. Yellow fever is common, though less frequent and severe among the blacks than the whites. Dysentery is common, though it has always been less frequent than among the troops. Organic heart disease is frequent. Liver diseases are uncommon. Spleen disease, in the form of leucocythæmia, is common among the blacks (Smarda). Gout is said to be frequent, and scrofula and rickets to be infrequent. Syphilis is not common, but gonorrhœa is. Cancroid of the skin and elephantiasis of the Arabs (Pachydermia) are common. Leprosy is also seen.

Health of the Troops.

In the years 1790–93 the annual mortality of the white troops varied in the different stations from 111 (Montego Bay) to 15·7 per 1000 of strength at Stoney Hill (1380 feet above sea-level). In the years 1794–97 the mortality was much greater; the most unhealthy regiment in the plains lost 333; the most healthy, 45·4 per 1000 of strength; at the hill station of Maroon Town (2000 feet), the mortality was, however, only 15·6 per 1000. In the years 1817–36 the mean mortality was 121·3; the mean of the four healthiest years gave 67, and of the four unhealthiest years 259 per 1000. The causes of death in these twenty years were—

Fevers, ...	101·9	per 1000 of strength.
Lung diseases, . . .	7·5	,,
Bowel complaints, . .	5·1	,,
Brain disease, . . .	2·6	,,
Liver diseases, . . .	1	,,
Other complaints, . .	3·2	,,
	121·3	,,

The admissions in these years were 1812 per 1000 of strength. In 1837–55 the following were the mean results :—Mortality per 1000 of strength—white troops, 60·8; black troops, 38·2. Admissions per 1000—white troops, 1371;

black troops, 784. So that the mortality had declined one-half. At present the statistics of the white troops are—

Years.	Loss of Strength per 1000 per Annum.			Loss of Service per 1000 per Annum.		
	Total Deaths.	Deaths from Disease.	Invalids.	Admissions.	Mean Daily Sick.	Days in Hospital to each Sick Man.
1859–66 (8 years), .	15·52	14·03	27·18	1062·8	61·14	17·34
1867 (highest in 1867,	71·09	69·80	45·91	1192·9	78·95	21·95
Lowest in 1864, .	7·35	5·88	...	...	...	...

In 1864 the mortality was much below the home standard. In 1867 it ran up nearly to the old amount, from the prevalence of yellow fever, which in that year prevailed again in Newcastle, and caused a greater loss than it had done in 1860.

But before this an increase in admissions and mortality had occurred in 1865 and 1866, owing to the exposure of the troops in the time of the negro disturbances, and their subsequent partial location on the plains.

Before this period Jamaica contrasted favourably even with home service, and particularly so with India.

The decrease of admissions in 1859–64 was chiefly owing to the comparatively small number of cases of paroxysmal disease; a decline consequent on the removal of most of the troops from the plains (in 1859 Newcastle gave 29·1 admissions, and Port-Royal, on the plain, 443·5 per 1000 of strength, from malarious disease). In 1863 some white troops were sent to Up-Park Camp, and furnished a large number of malarious cases (547·6 admissions per 1000 of strength), while at Newcastle they were only 48 per 1000. The decrease in the mortality in the years 1859–64 was owing to lessened fever and dysentery. Among the black troops there is now greater sickness and mortality than among the whites; the mortality in 1837–55 was 38·2 per 1000; in 1859–65 it was 27·33; and in 1866, 23·03 per 1000. There is among these troops a large mortality from paroxysmal fevers, phthisis, and diseases of the alimentary canal; and it is evident that their condition requires a close examination.

The mortality of the white troops shows a marked increase with age.

The following seem to be the most important points connected with the white troops which require notice.

It is impossible to avoid paroxysmal fevers without placing all the troops in the hills, and it is very desirable Newcastle should be made the only station for white troops.

The possibility of yellow fever occurring at an elevation of 4000 feet, was shown by the appearance of yellow fever at Newcastle in 1860. In that year occurred the remarkable instances of contagion on board the ships Icarus and Imaum described by Dr Bryson. Whether yellow fever was imported into Newcastle or not was a subject of discussion; it certainly appears probable that it was carried there; but the important point for us is that mere elevation is not a perfect security. There were, however, only a small number of cases. In 1867, yellow fever again appeared at Newcastle, being imported, apparently, from Kingston and Up-Park Camp.

In the returns for a number of years past, cases are returned as "continued fever;" it has never yet been clearly made out whether or not these were cases of typhoid fever; but the existence of typhoid fever in the other West Indian Islands, as in Trinidad, in India, on the west coast of Africa, in Algeria, and in other tropical countries, makes it probable that typhoid fever does occur in Jamaica.

Formerly there were a large number of cases of phthisis; phthisis is now uncommon; in 1817–36 lung diseases (almost entirely phthisis) caused 7·5 deaths per 1000 of strength, or more than in England. In 1859–66 the ratio was only 1·42 per 1000 of strength; and in 1861, out of 636 men there was not a single death, though four men were sent home with consumption. In 1865 there was no death; eight men were sent home.

At Newcastle there occurred for some years an excess of affections of the alimentary canal, chiefly indigestion; at present these have lessened, but it would be important to make out the cause. In 1860 there was not a single admission from dysentery at any station.

In the worst times in Jamaica it was always remarked that there was rather a singular exemption from acute liver disease; very few cases appear in the returns under hepatitis; whether this is a matter of diagnosis, or whether there was really an immunity compared with India or the Mauritius, is a question of great interest which cannot now be solved. At present, liver disease unconnected with drinking is uncommon.

There is still too much drinking, and the medical officers have strongly advised the issue of beer instead of the daily dram.

Venereal diseases have never prevailed much in Jamaica; they have caused, on an average, from 70 to 90 admissions per 1000 of strength. In 1862 there were only 47 admissions per 1000 of strength. On an average in 1859–65, enthetic diseases gave 118 admissions per 1000. This is owing to the connection usually formed between the black women and the soldiers, and to a lessened amount of promiscuous intercourse.

The history of the years 1865–67 shows that the greatest care and the most judicious arrangement of the men is necessary to guard against a recurrence of the old evils.

Trinidad.

Strength of garrison, 200 men.

Geology.—Tertiary formation of miocene age; central range of hills is an indurated formation of cretaceous age; the northern littoral range consists of micaceous slates, sandstones, limestones, and shales. The highest hill is 3012 feet; the central hill (Tamana) is 1025; $\frac{1}{17}$th of the island is swampy.

Climate.—Temperature of the plains: Mean of year about 79°·3; coldest month, January = 78°; hottest month, May = 81°·5; next hottest, October = 80°·4. Mean annual fluctuation, 3°·5. The climate is therefore very equable and limited. There are, however, cold winds from the hills blowing over small areas.

Hygrometry.—Mean dew-point, 75°·1, mean relative humidity = 81 per cent. of saturation; mean weight of vapour in a cubic foot = 9·4 grains; most humid month is May, as far as the amount of vapour is concerned. Month with greatest relative humidity, August.

Winds from east to north-east and south-east. West winds rare, and oppressive.

Rain on the Plains about 60 to 70 inches. Greatest rainfall in one day, 4·67 inches. Dry season, December to May. June and July showery. Heavy rain in August, September, and October.

Sanitary Condition.—St James' Barrack is on a depression on an alluvial soil three miles from Port of Spain, the capital; it is one mile from the Cocorite, and three from the Great Eastern Swamp; the drainage, for many years most defective, is now improved, as the main sewer is carried to the sea. On many occasions yellow fever has prevailed in this barrack, and nowhere else in the island; the last occasion was in 1858–59, and then it was proposed by Dr Jameson (the principal medical officer) to erect barracks on a spot 2200 feet above sea-level.

The capital, the Port of Spain, is built at the principal outfall of the island; it is on a low and unhealthy plain. Formerly, it was so unhealthy as to be scarcely habitable, but after being well drained and paved by Sir Ralph Woodford, it became much healthier. This was the result of great sanitary efforts in a very unpromising locality, and should be a lesson for all climates.

There is still, however, much malarious disease, dysentery, and at times yellow fever; but this last disease has occasionally been very severe at St James's Barracks, without a single case being seen in Port of Spain. The ascent of the malaria from the barrack plain is certainly more than 500, and probably as much as 1000 feet.

Diseases of Troops.—The state of health has been and is very similar to that of Jamaica, with, however, a larger percentage in former years both of phthisis and diseases of the stomach and bowels, chiefly dysentery.

In the years 1817–36, the average mortality of the white troops was 106·3 per 1000 of strength, and of these deaths there were—

From Fevers,	61·6
Lung diseases,	11·5
Diseases of stomach and bowels,	17·9
Dropsies (probably partly malarious, partly renal),	7·7
Brain disease (especially from intemperance),	4·7
Liver diseases,	1·1
All other diseases,	1·8
	106·3

As in Jamaica, the statistics of the white troops of late years tell a very different story.

In 1859 there was an outbreak of yellow fever, and the deaths from disease rose to 84·27 per 1000. In the next seven years (ending 1866) the average number was 7·48 deaths from disease per 1000. In two years (1860 and 1865) there were no deaths.

Even in 1859, when the mortality was so large, there were only 10 deaths from yellow fever among 190 men, while there were no less than 4 deaths from delirium tremens.

Among the diseases in the returns, the largest item is malarious fever; there are also cases of "continued fever," as in Jamaica; and this term, in fact, has never been absent from the reports. Is this typhoid fever? In all probability it is, as unequivocal typhoid fever does occur in Trinidad. (See Dr Stone's paper in the "Medical Times and Gazette," Feb. 1868). A considerable number of cases of dyspepsia are admitted; in 1860 there were 16 cases out of 221 men, or 72 per 1000 of strength. In 1862 there were 103 per 1000 admissions from "digestive" diseases. Venereal diseases have always been low; in 1860, 1861, 1862, and 1864, there were only 49·8, 44·4, 20·6, and 63·8 admissions per 1000 of strength. Dysentery is now infrequent. In 1860, out of 221 men, and in 1861, out of 225 men, there was not a single case.

In 1864, out of 235 men, there was only 1 case. In 1865 there were no admissions from phthisis. Phthisis is much less common, yet in some years there is still too much of it.

It is evident that if Dr Jameson's suggestion is acted upon, and the troops are removed to the hills, malarious fever will disappear, and yellow fever can be prevented. In such a case, if the men will abstain from drinking, this island, which formerly killed rather more than 1 man in every 10 yearly, will be one of the healthiest spots in the world.

The black troops are now less healthy than the white, having in 1859–65 an annual mortality of nearly 20 per 1000, of which 18 were from disease. Their condition requires looking into. Of late years a very small number of black troops have been stationed at Trinidad.

The invaliding from Trinidad is combined in the Army Reports with that of the other islands of the Windward and Leeward Commands.

Barbadoes.

Strength of garrison, 500 to 600 men.

Geology.—Limestone (coralline); sandstone (tertiary); beds of bituminous matter and coal (tertiary), clay in parts (especially in the hilly district called "Scotland").

An open country, well-cultivated, no marshes except a small one at Græme Hall, one mile to the east of St Ann's Barracks.

The country is divided into two parts: a mountainous district termed "Scotland," and a lower country consisting of a series of five gigantic terraces, rising with some regularity one above the other. The highest hill is 1100 feet.

Climate of the Plain.—Temperature: Mean of year, 80°; hottest month (October), 83°; coldest month (January), 78°; mean yearly fluctuation, 5°. Climate equable and limited.

Wind.—N.E. trade, strongest in February to May; weak in September to November inclusive; hurricane month, August.

Rain.—About 56 to 58 inches, on an average, but varying a good deal in the autumn chiefly, though there is rain in all months, but much less. The dry season is from December to May.

Water.—Formerly supplied from wells; it was highly calcareous. At present good water is supplied by a water company. Rain water is also collected in tanks.

Sanitary Condition.—St Ann's Barracks are placed above one and a half mile from Bridgetown, on the sea; the locality and the construction of the barracks have been much complained of, and a position in the hills advised.* Arrangements for sewering and the water supply were both formerly bad; considerable improvements have been made, and, since 1862, 30,000 gallons are supplied daily to St Ann's Barracks. It is a limestone water, containing carbonate of lime, but no sulphate of lime, and is remarkably free from organic matter. The total solids are 18·72 grains per gallon. The troops are still too much crowded in barracks, the allowance being under 600 cubic feet.

Formerly vegetables were very deficient in Barbadoes, and even now there is some difficulty in procuring them. They are often imported from other islands.

Diseases among Civil Population.—Yellow fever has appeared frequently,

* For an extremely good and concise account of Barbadoes, see Dr Jameson's Report in the Army Medical Report for 1861, p. 261.

although the island is not marshy. It is not so frequent as formerly; it used to be expected every four years.

Barbadoes and Trinidad contrast greatly in the freedom from marshes of the one, and the existence of marshes and malarious disease in the other; yet Barbadoes has had as much yellow fever as Trinidad.

Dysentery was common formerly, partly from bad water; influenza has been epidemic several times. Barbadoes leg, or Elephantiasis of the Arabs, is frequently seen. Leprosy, or Elephantiasis Græcorum, is also not very uncommon. Variola and Pertussis have from time to time been very bad.

Hillary, in 1766, described a "slow nervous fever," under which term our typhoid fever appears to have been indicated by most writers of that period. His description is not quite clear, but resembles typhoid fever more than any other. He also speaks of "diarrhœa febrilis." Can this have been typhoid?

Dracunculus was formerly very frequent, and Hillary attributes it to the drinking water, and states that there were some ponds, the water of which was known to "generate the worm if washed in or drank."

Yaws used to be common.

Colica pictonum was formerly frequent.

Diseases of Troops.—Yellow fever has several times been very fatal.

Scorbutic dysentery, arising from the wretched food, was formerly very frequent, and appears from Sir Andrew Halliday's work to have been very bad even in his time (1823 to 1832).

From 1817 to 1836 (20 years)—

Average Mortality (white troops),	58·5	per 1000 of strength.	
Greatest ,, .	204	,, ,,	(in 1817).
Least ,, .	18	,, ,,	(in 1823).

In 1817 there were 1654 men on the island, and yellow fever broke out. In 1823 there were only 791.

Of late years, as in all the other islands, the sickness and mortality has been comparatively trifling.

In 1859–65 the total deaths were 6·98 per 1000, and in 1866 they fell to 3·28 per 1000, which is only ⅓d the mortality of home service. The highest mortality of late years was in 1862, viz., 16·77; the average number of admissions is about 1200.

In 1864 there was an outbreak of a mild fever, termed "remittent;" the nature is unknown; no case was fatal.

The increased mortality of 1862 was owing to fellow fever. It appeared first among the civil population in Bridgetown, and afterwards attacked the troops in the (stone) barracks. As it continued to spread, the men were moved out and placed under canvas, with the best effects. A remarkable feature of this epidemic was that the officers suffered in attacks six-fold more than the men, and had a mortality more than twenty-fold. The women also suffered three-fold more than the men. Formerly the case would have been reversed. In 1861 there were only two deaths out of 787 men, one from phthisis and one from apoplexy; and in 1864 there were also only two deaths (diarrhœa and phthisis) among 930 men.

Dysentery is now uncommon.

The great improvement to be made at Barbadoes is decidedly a complete change of barracks. The persistent recurrence of yellow fever in these old barracks, with their imperfect arrangements, shows them to be the main cause of the appearance of the disease. The cost of a single epidemic would amply repay the outlay.

As in the other islands, the black troops are now much more unhealthy than the white, and the sanitary condition of their barracks and their food

evidently require looking into. Phthisis and chronic dysentery are the chief diseases causing mortality. The average of 1859–64 gave 1015 admissions and 20·46 deaths per 1000 of strength. In 1865 there were 22·54 deaths per 1000 of strength, or, excluding violent deaths, 20·49; of these phthisis caused 14·34, or no less than 70 per cent. of total deaths.

St Lucia.

Strength of garrison = 100 men, now usually black troops.

St Lucia is divided into two parts: Basseterre, the lowest and most cultivated part, is very swampy; Capisterre, hilly, with deep narrow ravines, full of vegetation. The climate is similar to that of the other islands, but is more rainy and humid.

Diseases of the White Troops.—From 1817–36; average strength, 241; average deaths, 30 = 122·8 per 1000 of strength. Of the 122·8 deaths, 63·1 were from fevers, 39·3 from bowel disease, and 12·5 from lung disease.

Pigeon Island (a few miles from St Lucia) was formerly so unhealthy that on one occasion 22 men out of 55 died of dysentery in one year, and of the whole 55 men not one escaped sickness. The cause is supposed to have been bad water. Now, Pigeon Island is considered healthy.

Although the mortality was formerly so great, St Lucia has been very healthy for some years.

In 1859, mean strength of white troops, 96; admissions, 113, and there was not a single death, although, if the mortality had been at the rate of the twenty years ending 1836, 12 men would have died.

Better food, some improvement in barracks, and the use of rain instead of well water, have been the causes of this extraordinary change.

22 men were admitted with "continued fever," 18 with ophthalmia, and only two with venereal.

In 1860 there was no case of dysentery and only two of diarrhœa among 100 men in this island, where formerly there would have been not only many cases, but four deaths. One man died from phthisis, or at the rate of 10 per 1000.

In 1861, out of 94 men, there was one death from jaundice, or at the rate of 10·6 per 1000.

In 1862, there were 88 men on the island; one man was drowned; there was no death from disease. No case of jaundice was admitted.

In 1863 there were 55 men, and one death from accident; there were 64 admissions, of which 15 were accidents.

Invaliding.—In 1860–65 there were discharged from the Windward and Leeward Command 28·86 per 1000 of strength.

British Guiana.

Strength of garrison = 200 to 300 men.

This other station in the West Indian Command is on the mainland, extending from the equator (nearly) to 10° N., 200 to 300 miles, and inland to an uncertain distance.

It is a flat alluvial soil of clay and sand, covered with vegetation.

The water is not good; it is drawn from a fresh-water lake and an Artesian well; the water from this well contains a good deal of iron.

Trade-winds from N.E. and E. for nine months. In July, August, and September, S.E. and S. and land-winds. This is the unhealthy season.

Two wet seasons, January and June; the last is the longest.

Temperature of summer, 86°; of winter, 82°. Rain about 160 inches.

Formerly there was an enormous mortality among the troops from yellow fever and scorbutic dysentery. The men used to have salt meat five times a week.

The climate is most highly malarious, but this does not cause much mortality.

Yellow fever has prevailed here several times. On one occasion (1861) the troops were moved out and encamped at some distance from Georgetown; they escaped (seven mild cases only), although they were on a swampy plain.

In 1817–36, the average deaths were 74 per 1000 of strength.

In 1859, out of a mean strength of 143, there were 156 admissions = 1091 per 1000 of strength; 2 deaths = 13·9 per 1000 of strength. One death from apoplexy, one from drowning. The deaths from disease were only 6·9 per 1000. Of the 156 admissions, no less than 81 were from malarious disease, or at the rate of 519 per 1000 of strength, or nearly one-half the total admissions.

In 1860, 1861, and 1862, the admissions from malarious disease continued high (673, 1380, and 1104 per 1000 of strength), the mortality was very small, being only 6·6 per 1000 in each year; in fact, the single death in 1860 and in 1861 was in one year from "acute hepatitis," and in the other from accident. In 1862, in spite of the immense malarious disease, there was no death. In 1863, there was a great reduction in the admissions from malarious disease; there were only 51 admissions among 133 men, or 377 per 1000 of strength. There was no death in that year. In 1864, there was 74 admissions from malarious disease among 125 men, but no death; there were 92 admissions from "continued fever," and 3 deaths; there was one death from yellow fever, which prevailed among the shipping and civilians. In 1865, there was an increased number of admissions from paroxysmal fevers; in 8 months they caused 260 admissions into hospital; out of 117 men there were 5 cases of yellow fever and one death. In 1866, there was also a large number of cases from malarious, and an outbreak also of yellow fever. Some important lessons are drawn from the medical history of this station. It has been shown that even in a highly malarious country yellow fever is not common, and that it may be escaped by change of ground, although the men are obliged to encamp on a swamp. Another remarkable point is the very small mortality attending the paroxysmal fevers. It would be very interesting to know the future history of such men, but it cannot be doubted that the lessened mortality since former years must be owing to better treatment.

The extent of malarious disease shows how desirable it would be to avoid sending white troops to Demerara, or, if this cannot sometimes be avoided, to change the men every year, and, during their service, to use quinine as a prophylactic regularly. The white troops are now (1869) withdrawn, and it is to be hoped will not again serve in this station.

In French Guiana, Dr Laure, besides malarious fevers, describes typhoid fever to have been seen for some short time after the arrival of French political prisoners after the *coup d'état* of 1851. It then disappeared.

BAHAMAS AND HONDURAS.

The black troops garrison both those places, and show a degree of mortality nearly the same as in the other stations, the amount of phthisis being very great. In 1862, at the Bahamas, there were no less than 4 deaths from phthisis out of a strength of 439, or at the rate of 9·1 per 1000 of strength; there were also 3 deaths from pneumonia and 1 from pleurisy In the year

1859–66 the average deaths from tubercular diseases per 1000 men, were 11·04 yearly, and from other diseases of the lungs, 5·86; out of 100 deaths 60 were from diseases of the lungs. This is evidently a matter for careful inquiry.

At Honduras, among the black troops, the deaths from tubercular disease, in 1859–66, were 4·04 per 1000 of strength.

SECTION III.

BERMUDA.

Usual strength of garrison about 1108 to 1300 men.

Climate.—Hot, equable, and rather limited.

Temperature.—Mean of year, 74°; hottest month (July), 83°·5; coldest month (February), 64°·5; amplitude of yearly fluctuation, 19°·0.

The sanitary condition is very bad; there are no sewers, and no efficient dry method removal. Rain water is used for drinking.

Diseases of the Troops.

Years.	Loss of Strength per 1000 per annum.			Loss of Service per 1000 per annum.		
	Total Deaths.	Deaths from Disease.	Invaliding.	Admissions.	Mean Daily Sick.	Days in Hospital to each Sick Man.
1817–36, . .	28·8	...	...	768	...	...
1837–46, . .	35·5	...	...	1080	...	...
1859–66 (8 years),	32·87	30·52	19·9	718·8	40·93	20·78
1867, . . .	17·61	12·79	19·2	738·9	36·03	17·80
Highest in 1864 (yellow fever year), . . .	169·54	168·63	...	...	...	...
Lowest in 1860,	8·55	5·70	...	...	...	...

If the yellow fever year (1864) be excluded, the total death average (1859–66) is 15·3, or from disease alone about 12.

This history of the West Indies may be applied to Bermuda, though, with the exception of yellow fever years, it never showed the great mortality of the West Indies. There is no great amount of paroxysmal fevers; in ten years (1837–46) there were only 29 admissions out of an aggregate strength of 11,224 men.

Yellow fever has prevailed seven times in this country—viz., in 1819, 1837, 1843, 1847, 1853, 1856, and 1864.

The history of the yellow fever in 1864 is given in detail by Dr Barrow.*

The total mortality was 14 officers, 173 men, 5 women, and 4 children. The deaths to strength were, among the officers, 18·9, and among the men, 14·9 per cent. The officers' mortality was owing to a large number of deaths among the medical officers.

The town of St George's, in Bermuda, presents every local condition for the spread of yellow fever; the town is quite unsewered; badly supplied with water; badly built.

* Army Medical Report, vol. v. p. 290.

"Dandy fever," or break-bone (Dengue), has prevailed several times.

"Continued fevers" (no doubt in part typhoid) have always prevailed more or less at Bermuda. In the ten years (1837–46) they gave 1004 admissions out of 11,224 men, or 88 per 1000 of strength, being much greater than at home.

In 1859 there were only 11 cases of "continued fever" out of 1074 men; but in 1860 "continued fever" prevailed severely (209 cases in 1052 men). It was of a mild type, and caused little mortality. It was probably not typhoid, but I have learned nothing definite of its nature. It prevailed in September, October, and November. Was it mild, bilious, remittent, or "relapsing fever?" It is said that the drainage was defective at Hamilton.

In 1866 there was decided typhoid fever, and a considerable mortality.

Formerly tuberculous diseases caused a considerable mortality. In the years 1817–36, diseases of the lungs gave a mortality of no less than 8·7 per 1000 of strength. In 1837–46, the lung diseases gave a yearly mortality of 8·3 per 1000 of strength. Of late years the amount has decreased. The admissions and deaths respectively were 10·5 and 2·6 in the seven years 1859–65.

Diarrhœa and dysentery were also formerly very common, but of late years there has been a great decrease. Diseases of the eyes are common.

There has always been much intemperance, and a large number of deaths from delirium tremens. This was the case even in 1866; there were no less than 5 deaths out of a total of 28.

Venereal (enthetic) diseases have averaged from 55 to 80 per 1000 of strength.

In considering the sanitary measures to be adopted at Bermuda, it would seem that drainage and ventilation are still most defective, and that means should be taken to check intemperance. If yellow fever occurs, the measures should be the same as in the West Indies.

SECTION IV.

AMERICAN STATIONS.

Sub-Section I.—Canada.*

Usual garrison, from 3000 in profound peace, to 10,000 or 12,000 in disturbed times. In 1862, it was 10,763; in 1866, it was 9519.

Lower Canada.

Chief Stations.—1. *Quebec.*

Temperature.—Mean of year, 41°; hottest month (July), 71°·3; coldest (January), 11°. Annual fluctuation, 60°·3.

The undulations of temperature are enormous. In the winter, sometimes, there is a range of 30, 40, and even more degrees in 24 hours, from the alternation of northerly and southerly winds. In one case the thermometer fell 70° in 12 hours. The mercury is sometimes frozen.

The mean temperature of the three summer months is 69°; winter months, 12°·8. The climate is "extreme" and variable.

Rain.—About 36 to 40 inches. The air is dry in the summer, and again in the depth of winter.

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* For an excellent account of the Canadian stations, see Dr Muir's Report on the Army Medical Report for 1862, p. 375.

Barracks.—Built on lower Silurian rocks. No ague is known, though the lower town is damp.

Amount of cubic space small. Casemates in citadel very bad, damp, ill ventilated, ill lighted.

2. *Montreal.*

Temperature.—Mean of year, 44°·6 ; hottest month (July), 73°·1 ; coldest (January), 14°·5. Annual fluctuation, 58°·6. The undulations are very great, though not so great as at Quebec.

Mean of the three summer months, 70°·8 ; of the three winter months, 17°·2.

Rain.—36 to 44 inches.

Barracks.—Bad ; very much overcrowded.

In Lower Canada are also many smaller stations.

UPPER CANADA.

Chief Stations.—1. *Toronto.*

Temperature.—Mean of year, 44°·3 ; hottest month (July), 66°·8; coldest (February), 23°·1. Difference, 43·7. Great undulations.

Rain.—31·5 inches.

The town stands on ground originally marshy. The new barracks are built on limestone rocks of Silurian age. Average cubic space, only 350. Drainage bad.

Intermittent fevers among the civil population; not very prevalent among the troops.

2. *Kingston.*

Temperature.—Mean of year, 45°·8.

Malarious.

London, Hamilton, and several smaller stations—Fort George, Amherstberg, &c.—are also occupied.

Diseases of the Civil Inhabitants.

Formerly ague was prevalent in Upper Canada, especially in Kingston; it is now much less. At Montreal ague used to be seen; now is much less frequent. It prevails from May to October, and is worst in August.

If the isothere (summer temperature) of 65° be the northern limit of malaria, both Quebec and Montreal are within the limit; yet the winter is too severe, and the period of hot weather too short, to cause much development of malaria.

The climate is in both provinces very healthy, and has been so from the earliest records, though, when the country was first settled, there was much scurvy.

Typhoid is sometimes seen. Typhus has been often carried in emigrant ships, but has not spread, or at least has soon died out. Cholera has prevailed. Yellow fever dies out. Consumption is decidedly infrequent.

Acute pulmonary diseases used to be considered the prevalent complaints, but it is doubtful whether they are much more common than elsewhere.

Diseases of the Troops.

Years 1817–36 (20 years).—Admissions per 1000 of strength = 1097 ; deaths 16·1 (without violent deaths).

Years 1837–46 (10 years).—Yearly admissions per 1000 of strength, 982; average daily sick per 1000 of strength, 39·1 ; mortality (violent deaths excluded), 13; mortality with violent deaths, 17·42.

The mortality was made up in part of—fever, 2·13; lung disease, 7·44; stomach and bowels disease, 1·11; brain disease, 1·28. Nearly two-thirds of the fevers are returned as "common continued," probably typhoid.

Venereal admissions, 117 per 1000.

Erysipelas was epidemic at Quebec, Montreal, and Toronto in 1841; at Montreal in 1842, from bad sanitary conditions.

The following table shows the mean of the later years:—

Years.	Loss of Strength per 1000.			Loss of Service per 1000.		
	By total Deaths.	By Deaths from Disease.	By Invaliding.	Admissions.	Mean Daily Sick.	Days in Hospital to each Sick Man.
1859–65, (7 years.)	9·74	7·26	15 (5 years.)	661·9	29·69	16·37
1866, . .	10·10	7·99	...	715·5	39·29	20·04
1867, . .	9·87	7·64	...	729·4	...	...

These numbers show, what indeed is apparent in all the records, that Canada is a very healthy station.

The amount of phthisis has always been smaller than on home service, and regiments of the Guards proceeding from London to Canada have had on two occasions a marked diminution in phthisical disease.

In this respect, also, Canada contrasted formerly with the West Indies, but of late years the decline of phthisis in the West Indies has lessened the superiority of Canada.

The comparatively small amount of phthisis is remarkable, as the troops have at times been very much crowded in barracks. They have now the home allowance of space (600 cubic feet).

Of late years phthisis has declined considerably with improved barrack accommodation.

In the 20 years, 1817–36, the annual admissions were 6·5, and the deaths 4·22, per 1000 of strength.

In the years 1859–66 the admissions from the whole tubercular class were 8·3, and the deaths were 1·67, per 1000 of strength.*

It is curious to observe that this diminution has been coincident with a similar change at home.†

The acute lung affections, pneumonia, and acute bronchitis, appear formerly to have been rather more prevalent in Canada than they are now.

The following table gives the mean and extremes for 8 years (1859–66):—

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* Still the lung complaints are higher than they should be. Dr Muir, C.B. (Army Med. Report, vol. viii. p. 56), after detailing the measures taken by him to improve the barrack accommodation, says, "I cannot help thinking that the large number of men treated and invalided for chest disease, during the five years I have been in this command, bears a close relationship to this impure state of barrack air."

† In contrasting the consumptive invalidity at Gibraltar, Bermuda, and Canada, the Reporters of 1839 (Army Med. Report) remark that the returns "afford another interesting proof how little the tendency to consumption is increased either by intensity of cold or sudden atmospherical vicissitudes." See also the remarks on Phthisis in India at a subsequent page.

	Per 1000 of Strength. Admissions.	Deaths.
Pneumonia—Mean, . . .	12·24	·8576
Highest, . . .	15·33	1·996
Lowest, . . .	7·91	·411
Acute bronchitis—Mean, . .	42·67	·309
Highest, . .	49·79	·719
Lowest, . .	28·48	·092
Average of the mean of both, .	27·45	·5833

If this table is compared with the similarly constructed table (at page 541), showing the prevalence of these diseases at home, it appears that both pneumonia and acute bronchitis are rather more fatal in Canada. Both together give a mortality of ·856 per 1000 at home, and 1·166 per 1000 in Canada. The admissions from pneumonia are also higher, but those from acute bronchitis are one-third less than at home, showing that the common catarrhal affections are probably less frequent in Canada. On the whole, however, the influence of the severe climate and the exposure on guard in Canada produces less effect than might have been anticipated.

"Continued fevers" (probably enteric) almost yearly give some mortality; the mean being about ·6 per 1000 of strength. This is actually more than on home service, and depends probably on the difficulties connected with drainage. A good dry system is the only plan which can be depended on in Canada.

The great healthiness of Canada in part probably depends on the fact, that the extreme cold in winter lessens or prevents decomposition of animal matter and the giving off of effluvia; hence, in spite of bad drainage and deficient water, there is no very great amount of fever. In the hot summer, the life is an open air one. Even in winter the dry cold permits a good deal of exercise to be taken.

The amount of drunkenness and delirium tremens in Canada used to be great, and is still so considerable as to show that something should be done to check it. In 1863 no less than 9 out of 96 deaths, or nearly $\frac{1}{10}$th, were caused by delirium tremens. Violent deaths also are unusually large; drowning giving the largest proportion.

Sub-Section II.—Nova Scotia and New Brunswick.

Strength of garrison, 1500 to 4000 men.

The state of health at these stations is almost identical with that of Canada, and it is hardly necessary to do more than cite the figures of the earlier and later years.

Years.	Loss of Strength per 1000.		Admissions.	Loss of Service per 1000.	
	With Violent Deaths.	Deaths from Disease.		Number constantly Sick.	Days in Hospital to each Sick Man.
1837–1856, . . .	15·3	15·1	836	34·8	...
1859–1865, . . .	7·4	6·03	573·6	26·04	16·57
1866, . . .	7·7	6·24	493·6	23·10	17·08
1867, . . .	7·68	5·91	489·5	23·03	17·17

The remarks already made in respect of Canada apply to Nova Scotia.

Continued fever (typhoid) causes some mortality every year, and should be prevented. Drunkenness and delirium tremens are less common than they were, but still prevail too much.

Sub-Section III.—Newfoundland.

Garrison about 200 to 300.

Newfoundland has had the reputation of being extremely healthy ever since it has been garrisoned, or even frequented by sailing ships (Lind). Among the troops, the Colonial Battalion (now disbanded) has had remarkable health, and if drunkenness had been avoided, it would have been almost unexampled.

In 1837–56 (twenty years) the average yearly admissions per 1000 were 689, and the deaths 11.

In 1859–65 the admissions were 662, and the deaths 7·7 per 1000, or much below the home standard in men of the soldier's age. At present Newfoundland is garrisoned by the Canadian Rifles, who are younger men than the men of the old colonial corps (the Royal Newfoundland Companies).

The causes of sickness and mortality are the same as those in Canada.

Sub-Section IV.—British Columbia.

Garrison, 100 to 150 men.

New Westminster is to be the capital. Lat. 49° 12′; long. 122° 49′.

Soil.—Gravel, sand, and clay.

Climate.—The temperature of the hottest month, August, mean 69°·4; coldest month, January, mean 35°·7; mean yearly range, 33°·7.*

Rain, 56·42 inches, on 152 days. Relative humidity, 90·8 in December; in June 65 per cent. of saturation.

In 1861, in a force of 130, there were 97 admissions (22 catarrh (like, but not true influenza), 22 venereal, and 24 injuries), and 1 man frozen to death.

In 1862, in a strength of 160, there were 90 admissions (28 accidents, 24 sore throat, 19 diarrhœa, and 8 gonorrhœa), and one death from dropsy in an intemperate man.

In 1863 the deaths from disease were only 3·04 per 1000 of strength.

No measles, scarlatina, hooping-cough, or other zymotic diseases have yet been seen in the colony among the children.

It is probable, then, this colony will be found to be, like Canada, a very healthy one; in fact, out of the malarious range, America seems remarkably healthy.

SECTION V.

AFRICAN STATIONS.

Sub-Section I.—St Helena.

Garrison, 350 to 700.

Until very lately this small island has been garrisoned by a local corps (St Helena Regiment). This system is now altered, and a West India Regiment now serves in the island for three or four years.

The island has always been healthy; seated in the trade-winds, there is a tolerably constant breeze from south-east. The average mortality in the years 1859–66 was 9·75, or without violent deaths, 7·85. In 1867 the mortality from disease was only 5·24. There is very little malarious disease (about 50

* From Dr Seddall's paper in the Army Medical Report for 1859.

to 60 admissions per 1000 of strength), but there has frequently been a good many cases of "continued fever," and dysentery and diarrhœa are usual diseases. Formerly there appears to have been much phthisis, but this is now much less, giving another instance of the decline of this disease as in so many other stations.

In the years 1837–46, the admissions from tubercular diseases averaged 21 per 1000 per annum, and the deaths 5·45. In the years 1859–66 the admissions from tubercular diseases were 6·6; and the deaths 1·66 per 1000. In 1867 there were no admissions. The health of the troops would have been even better if the causes of the continued fever and dysentery could have been discovered and removed, and if the amount of drunkenness had been less.

Sub-Section II.—West Coast of Africa.*

The principal stations are Sierra Leone, Gambia, and Cape-Coast Castle, The troops are now (1869) withdrawn from Lagos (500 miles from Cape-Coast Castle, and occupied in 1861).

Sierra Leone.

Strength of garrison, 300 to 500 black troops, with a few officers and non-commissioned officers. Hot season from May to the middle of November; Harmattan wind in December; soil, red sandstone and clay, very ferruginous. There are extensive mangrove swamps to N. and S. Water very pure. The spring in the barrack square contains only 3 to 4 grains per gallon of solids.

This station had formerly the reputation of the most unhealthy station of the army. Nor was this undeserved.

From 1817 to 1837 (twenty years) there were yearly among the troops—

Admissions, . . .	2978 per 1000.
Deaths, ...	483 „

At the same time, about 17 per cent. of the whole white population died annually.

The chief diseases were malarious fevers, which caused much sickness, but no great mortality; and yellow fever, which caused an immense mortality. Dysentery, chiefly scorbutic, was also very fatal.

The causes of this great mortality were simple enough. The station was looked upon as a place for punishment, and disorderly men, men sentenced for crimes, or whom it was wished to get rid of, were draughted to Sierra Leone. They were there very much overcrowded in barracks, which were placed in the lower part of the town. They were fed largely on salt meat; and being for the most part men of desperate character, and without hope, they were highly intemperate, and led, in all ways, lives of the utmost disorder. They considered themselves, in fact, under sentence of death, and did their best to rapidly carry out the sentence.

Eventually, all the white troops were removed, and the place has since been garrisoned by one of the West Indian regiments. Of late years, the total white population of Sierra Leone (civil and military) has not been more than from 100 to 200 persons.

The great sickness and mortality being attributable, as in so many other cases, chiefly to local causes and individual faults, of late years Europeans have been comparatively healthy; although from time to time fatal epidemics

* For a very good account of the topography of the Gold Coast, see Dr R. Clarke's paper in the "Transactions Epid. Society," vol. i.

of yellow fever occur. They are, however, less frequent and less fatal than formerly. The position of the barracks has been altered, and the food is much better. One measure which is supposed to have improved the health of the place, is allowing a species of grass (Bahama Grass) to grow in the streets. The occupiers of the adjacent houses are obliged to keep it cut short, and in good order.

During the four years, 1863–66, there died 8 white non-commissioned officers, in the whole command of the West Coast, out of an average strength of 25, or at the annual rate of 80 per 1000 of strength. Three of the 8 deaths were from liver disease, two from delirium tremens, two from fevers, and one from dysentery. In 1867 two serjeants died, out of 15 white men—one from apoplexy, one from delirium tremens.

Among the black troops, the returns of the seven years 1859–65 give 875·8 admissions and 27·15 deaths (or 24·68, exclusive of violent deaths) per 1000. Among the causes of death, tubercular diseases hold the first place, amounting to 7·05 per 1000 of strength. In 1862 phthisis amounted to no less than 12·6 per 1000 of strength, and constituted 43·7 per cent. of all deaths from disease. There were also 9·46 per 1000 of strength deaths from pneumonia. In 1863 the deaths from phthisis were 9·3 per 1000 of strength, and made up 36·3 per cent. of the total deaths. In 1867 the tubercular deaths per 1000 of strength were 17·71 in Sierra Leone, 15·87 at the Gambia, and 12·58 at the Gold Coast and Lagos together. It seems clear, indeed, that in all the stations of the West India corps (black troops), the amount of phthisis is great; in fact, the state of health generally of these regiments requires looking into, as in the West Indies.

In 1862 there were only five cases of intermittent, and eighteen of remittent fever among 317 negroes.

In 1861 some of the troops from Sierra Leone and the Gambia were employed up the Gambia against the Mandingoes, and also against the chiefs of Quiat. In 1863 and 1864 the Ashanti war prevailed. All these wars added to the sickness and mortality, so that these years are not fair examples of the influence of the climate.

Gambia.

Garrison, about 200 to 400 (black troops). This station is much more malarious than any of the others. The drinking-water is bad; all barrack and sewage arrangements are imperfect. Yellow fever from time to time is very destructive. In 1859 two out of four European serjeants, and in 1860 three medical officers, died of yellow fever. Among the black troops in 1859–65 the admissions were 1169·8, and the deaths 29·97 per 1000 of strength.

As at Sierra Leone, phthisis and other diseases of the lungs cause a large mortality among the negroes. In 1861 phthisis gave five deaths out of a strength of 431, or at the rate of 11·6 per 1000 of strength; and pneumonia gave four deaths, and acute bronchitis three, or (together) at the rate of 16·24 per 1000 of strength. Phthisis, pneumonia, and bronchitis gave nearly 60 per cent. of all deaths from disease. This was higher than in previous years; but in 1862 phthisis gave 14·35 deaths per 1000 of strength, and constituted 75 per cent. of the whole number of deaths! There was, however, no pneumonia or bronchitis in that year. In 1866 the tubercular class give 9·53 deaths per 1000. In 1863, however, there were no deaths from phthisis. Although the period of observation is short, it can hardly be doubted that here, as elsewhere in the stations occupied by the West Indian regiments, some causes influencing the lungs prejudicially are everywhere in action. It is probably to be found in bad ventilation of the barracks.

Among the few white residents at the Gambia, diarrhœa, dysentery, and dyspepsia appear to be common. These, in part, arise from the bad water; in part from dietetic errors (especially excess in quantity), and want of exercise and attention to ordinary hygienic rules.

Cape-Coast Castle (Gold Coast).

Garrison, 300 to 400 (black troops).

This station has always been considered the most healthy of the three principal places. It is not so malarious as even Sierra Leone, and much less so than the Gambia, and has been much less frequently attacked with yellow fever. Dysentery and dyspepsia are common diseases among the white residents. Among the black troops the prevalence of phthisis, pneumonia, and bronchitis is marked, though less so, perhaps, than at the other two stations.

One peculiarity of the station is the prevalence of dracunculus. This is uncommon on Sierra Leone, and at the Gambia. It is, on the other hand, very frequent at Cape-Coast Castle.

Admissions from Guinea-Worm, per 1000 *of Strength.*

Garrisons.	1860.	1861.	1862.	1863.
Sierra Leone, . . .	2·6	...	...	11·62
Gambia, ...	...	...	...	...
Cape-Coast Castle, .	246	285	115	12·8
Lagos, ...	...	...	38	...

The investigation of the cause of dracunculus at Cape-Coast Castle is one which would well repay the trouble, so abundant is the material of observation; it would probably clear up the still doubtful points on the mode of ingress.*

Hygiene on the West Coast.

There is no doubt that attention to hygienic rules will do much to lessen the sickness and mortality of this dreaded climate. In fact, here as elsewhere, men have been contented to lay their own misdeeds on the climate. Malaria has, of course, to be met by the constant use of quinine during the whole period of service. The other rules are summed up in the following quotation from Dr Robert Clarke's paper;† and when we reflect that this extract expresses the opinion of a most competent judge on the effect of climate, we must allow that, not only for the West Coast, but for the West Indies, and for India, Dr Clarke's opinions on the exaggeration of the effect of the sun's rays and exposure to night air, and his statement of the necessity of exercise, are full of instruction:—

"Good health may generally be enjoyed by judicious attention to a few simple rules. In the foremost rank should be put *temperance*, with regular and industrious habits. European residents on the Gold Coast are too often satisfied with wearing apparel suited to the climate, overlooking the fact that exercise in the open air is just as necessary to preserve health there as it is in Europe. Many of them likewise entertain an impression that the sun's rays are hurtful, whereas in nine cases out of ten the mischief is done, not by the sun's rays, but by habits of *personal economy*. Feeling sadly the wearisome

* For anybody interested in the investigation of the anatomy of the dracunculus, Dr Bastian's paper in the Linnean Transactions (1863) can be recommended.

† Trans. of the Epidem. Soc. vol. i. pp. 123, 124.

sameness of life on this part of the coast, recourse is too frequently had to stimulants, instead of resorting to inexhausting employments, the only safe and effectual remedy against an evil fraught with such lamentable consequences. Europeans also bestow too little attention on ventilation, far more harm being done by close and impure air during the night than is ever brought about by exposure to the night air.

"Much of the suffering is occasioned by over-feeding." (P. 124.)

SUB-SECTION III.—CAPE OF GOOD HOPE.

Garrison, 4000 to 6000 men, chiefly Europeans.

The chief stations are Cape Town, Graham's Town, King William Town; Port Elizabeth, Algoa Bay, and several small frontier stations. At Natal there is also a small force. The climate is almost everywhere good; the temperature is not extreme nor very variable; the movement of air is considerable.

At Cape Town the mean annual temperature is 67°, with a mean annual range of about 38°.

Years.	Loss of Strength per 1000.			Loss of Service per 1000.		
	Total Deaths.	Deaths from Disease.	Invaliding.	Admissions.	Mean Daily Sick.	Days in Hospital to each Sick Man.
1859–65, .	10·87	8·96	29	913·5	48·61	19·75
1866, . .	10·62	10·14	17	1019·3	52·48	17·74
1867, . .	11·52	9·64	25·6	1240·9	61·57	18·11

Malarious diseases are very uncommon. Continued fevers (probably typhoid) are seen and are rather common, though not very fatal. In 1859–66 they gave a mortality of 1·25 per 1000. In the earlier periods dysentery and diarrhœa were very common; they are now less so; in many cases, especially in the small frontier stations, they were clearly owing to bad water.

Ophthalmia has prevailed rather largely, especially in some years; there is a good deal of dust in many parts of the colony, and it has been attributed to this; the disease is probably the specific ophthalmia (grey granulations), and is propagated by contagion. Whether it had its origin in any catarrhal condition produced by the wind and dust, and then became contagious, is one of those moot points which cannot yet be answered.*

The Cape has always been noted for the numerous cases of muscular rheumatism. Articular rheumatism is not particularly common. There is also much cardiac disease. The prevalence of this affection has been attributed to the exposure and rapid marches in hill districts during the Kaffir wars. In 1863 there was, however, less rheumatism than usual.

Taking the years 1859–66 as expressing tolerably fairly the effect, *per se*, of the station, we find that the whole colony gave 18·3 admissions and 1·90 deaths per 1000 of strength from diseases of the circulatory organs.

Dr Lawson† has lately contributed a valuable paper on this subject. He finds the death rate from diseases of the organs of circulation (mean of seven

* Dr Lawson has published a memoir on this subject (Army Medical Report, vol. v. p. 338), to which reference may be made.

† Army and Med. Depart. Report, vol. viii. p. 548.

years, 1859–65) as 1·91 per 1000 of strength. This is higher than at any other foreign station, as will be seen from the table copied by Dr Lawson.

Mortality from Diseases of the Circulatory Organs.

	Ratio per 1000 of Strength.		Ratio per 1000 of Strength.		Ratio per 1000 of Strength.
Cape of Good Hope,	1·91	Bombay, .	·80	Malta, . .	·53
New Zealand, .	1·18	Bengal, .	·86	Gibraltar, .	·70
Australia, . . .	1·72	South China,	1·16	Bermuda, .	1·25
Mauritius, . . .	·53	West Indies,	1·02	Nova Scotia,	·84
St Helena, . .	·31	Jamaica, .	·85	Canada, .	1·19
Ceylon, . . .	1·11	Ionia, . .	·84	Home, . .	·93
Madras, . . .	1·12				

This table shows an extreme diversity, hardly to be reconciled with differences of climate or duties.

Scurvy formerly prevailed much at the Cape, particularly in the Kaffir wars.

Venereal diseases have of late years been very common. The average admissions from "enthetic" diseases in 1859–66 were 248·5, and in 1867 they were 438·3 per 1000 of strength in the whole colony. In Cape Town alone, where facilities for promiscuous intercourse are greater, they are even more numerous. From the 16th April 1868 to the 16th October 1868 (= 6 months) an average strength of 865 men gave 315 admissions, or at the rate of 728 per 1000 per annum. A Contagious Diseases Prevention Act has just been brought into action in Cape Town.*

The Cape has always been considered a kind of sanitarium for India. Its coolness and the rapid movement of the air, the brightness and clearness of the atmosphere, and the freedom from malaria, probably cause its salubrity. It has been supposed that it might be well to send troops to the Cape for two or three years before sending them on to India. This plan has, I believe, never been perfectly tried; but in the case of regiments sent on hurriedly to India on emergency it has been said that the men did not bear the Indian climate well. Probably they were placed under unfavourable conditions, and the question is still uncertain.

As a convalescent place for troops who have been quartered in a malarious district it is excellent.†

SECTION VI.

MAURITIUS.

Garrison, about 1500 to 2000 men.

Mauritius in the eastern has been often compared with Jamaica in the western seas. The geographical position as respects the equator is not very dissimilar; the mean annual temperature (80° Fahr.) is almost the same; the fluctuations and undulations are more considerable, but still are not excessive; the humidity of air is nearly the same, or perhaps a little less; the rainfall (66 to 76 inches) is almost the same; and the physical formation is really not very dissimilar. Yet, with all these points of similarity in climatic conditions, the diseases are very different.

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* I have to thank Inspector-General Dr Lawson for his kind permission to read the Act, which is based on our own Contagious Diseases Prevention Act. It expressly orders that every known or reputed prostitute be inspected twice a-month. The effects of the Act will not be known for some time.

† See effect on the 59th Regiment in the Army Medical Report for 1859, p. 99.

Malarious fever was formerly not nearly so frequent as in Jamaica, and true yellow fever is quite unknown; Mauritius, therefore, has never shown those epochs of great mortality which the West Indies have had. Hepatic diseases, on the other hand, which are so uncommon in the West Indies, are very common in the Mauritius. For example, in 1859 there were 47 cases of acute and chronic hepatitis in 1254 men, while in Jamaica there was one case out of 807 men. In 1860 there were 31 admissions from acute hepatitis out of 1886 men; in Jamaica there was not a single case. In 1862 there were 12 cases of acute, 11 of chronic hepatitis, and 72 cases of hepatic congestion, out of 2049 men; in Jamaica, in the same year, there was only 1 case of acute hepatitis out of 702 men. This has always been marked; is it owing to an error in diagnosis, or to differences in diet? It can scarcely be attributed to any difference in climate. In 1863 the difference was less marked, but was still evident.

In 1866–67 a very severe epidemic fever prevailed in the Mauritius, which offers many points of interest. As already noted, the Mauritius has till lately been considered to be comparatively free from malaria. All the older writers I have consulted state this, and it is apparent from all the statistical returns. Deputy-Inspector Dr Francis Reid, in a late report,* mentions that he had served ten years in the Mauritius, and had looked over the records of the troops for twenty-four years. He found some records of intermittents, but he traced all these to foreign sources, viz., troops coming from India, China, or Ceylon, and presenting cases of relapses.

For the first time, in the latter months of 1866 and the commencement of 1867, malarious fevers of undoubted local growth appeared on the western side of the island.

The causes of this development are traced by Dr Reid, and also by Surgeon-Major Small and Assistant-Surgeon W. H. T. Power, in some very careful and admirable Reports.† During the last few years a large amount of forest land has been cleared, and there has been much upturning of the soil; coincidently the rainfall has lessened, and the rivers have become far less in volume. At the same time, there has been a large increase of population; a great defilement of the ground in the neighbourhood of villages and towns, so that in various parts of the island there has been a constant drainage down of filth of all kinds (vegetable and animal) into a loose soil of slight depth, resting on impermeable rock, which forms a great deal of the western seaboard. In 1866–67 there occurred an unusually hot season, and again a deficient rainfall. This seems to have brought into active operation the conditions which had been gradually increasing in intensity for some years. The development of the malaria was not so much on the regular marshy ground as on the loose contaminated soil already noticed.

That the fevers which in 1866–67 became so general was of malarious type, is proved by a large amount of evidence on the spot from both military and civil practitioners, and from the fact that many soldiers returned to England and had at home relapses of decided paroxysmal fevers. Dr Maclean also informs me that he has seldom seen spleens so enlarged as among the invalids from this fever, who arrived at Netley.

But in some respects this fever presented characters different from common paroxysmal fevers. There was no very great mortality among the troops, but it was excessively fatal among the inhabitants of Port Louis and many other towns

* Letter to the Director-General, Feb. 1867.

† Annual Report on the District Prison Hospitals in 1867 (Mauritius, 1868). On the Malarial Epidemic Fever of the Mauritius, Army Med. Depart. Report, vol. viii. p. 442.

and villages. It also lasted for many months, and was attended in many cases with symptoms not common in common paroxysmal fevers, viz., with yellowness of the skin and with decided relapses, closely resembling in these respects the common relapsing fever. Mixed up with it also was decided typhoid fever. The question whether the great bulk of the epidemic was a purely paroxysmal or malarious fever, with an independent subordinate outbreak of typhoid fever, or whether it was a composite affection like the "typho-malarial fever" of the American war,* or was mixed up with the contagious "Indian jail fever" imported by Coolies, is not a matter very easy to decide. The officers best qualified to judge (Drs Reid, Small, and Power) look upon it as a purely malarious disease, and have expressed themselves very strongly on this point.†

This much seems certain, that in various parts of the island the loose, porous, shallow soil had been gradually becoming more and more impure with vegetable matters, and in some cases animal excreta; that there had been a gradual diminution of the subsoil water, and that this reached its maximum in 1866, when the rains failed, and the hot season was prolonged. There coincided, then, an unusual impurity of soil, lowered subsoil water, consequent increased access of air, and heightened temperature. Under these conditions, a usually non-malarious soil gave rise to an epidemic fever, which was usually characterised (chiefly at any rate) by the symptoms referred to the action of marsh miasmata, and was curable by quinine.

In the Mauritius, as in Jamaica, a "continued fever" is not uncommon; this is now being returned in part as typhoid.‡ It has occasionally been imported. There are other fevers vaguely named "bilious remittent," "Bombay fever," "Coolie fever," &c. The last term denotes the communicable fever, so common in the jails in the Bengal Presidency. It prevailed in the jails in the Mauritius in 1863 and 1864, among the Hindoos. The "Bombay fever" is probably typhoid. Dysentery and diarrhœa have largely prevailed, but are now becoming less frequent, though still in too great amount. In this respect Jamaica now contrasts very favourably with the Mauritius; thus, in 1860, there were altogether 213 admissions per 1000 of dysentery and diarrhœa, and 6·8 deaths per 1000; in Jamaica, in the same year, there was not a single admission from dysentery, and only 19 from diarrhœa among 594 men, and no death. Cholera has prevailed five times (first in 1819; not afterwards till 1854; then again in 1856, 1859, and 1861. It appears to have been imported in all these cases). Formerly there was a large mortality from lung diseases; now, as in Jamaica, this entry is much less, not more than half that of former days. The deaths from phthisis per 1000 of strength were, in 1860, ·521; in 1861, 1·03; in 1862, 1·94 (but in this year 11 men were invalided for phthisis); and in 1863, 2. Venereal (enthetic) diseases give about 110 to 130 admissions per 1000 of strength. Ophthalmia prevails moderately; to nothing like the same extent as at the Cape.

In the earlier periods, owing to the absence of yellow fever, the mortality of the Mauritius contrasted favourably with that of Jamaica, but now it is greater.

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* As described by Woodward, "Camp Diseases of the United States Armies," by J. J. Woodward, M.D., Philadelphia, 1863, p. 77.

† The two latter gentlemen say, *Op. cit.* p. 453—"It was entirely of malarious origin, and in every form, we might say, perfectly curable by the administration of quinine in large doses." These observers entirely deny that it had any contagious properties.

‡ Dr Reid has no doubt of the frequent occurrence of typhoid for many years. He mentions an interesting fact, viz., that patients with true enteric fever were also affected with the malarious epidemic fever; this latter was, however, easily curable by quinine, but the typhoid fever, which was also present, was quite unaffected.

Per 1000 *of Strength.*

Years.	Loss of Strength.			Loss of Service.		
	Deaths (all Causes).	Deaths from Disease.	Invaliding.	Admissions.	Mean Daily Sick.	Days in Hospital to each Sick Man.
1817–36,	30·5	...	...	1249	68	20
1837–50,	24	...	...	909	...	...
1859–65,	18·81	17·09	37·92	822·7	37·46	16·62
1866, .	14·01	12·89	30·32	758	43·23	20·82
1867, .	40·95	...	...	2232·6	...	...

SECTION VII.

CEYLON.*

Garrison, 800 to 900 white troops; 1200 to 1500 black troops. Population, 1,800,000, including nearly 5000 Europeans. The stations for the white troops are chiefly Galle, Colombo, Kandy, and Trincomalee, with a convalescent station at Newera Ellia (6200 feet above sea-level). The black troops are more scattered, at Badulla, Pultan, Jaffna, &c.

Geology.—A considerable part of the island is composed of granite, gneiss, and hornblende granite rocks; these have become greatly weathered and decomposed, and form masses of a conglomerate called "cabook," which is clayey like the laterite of India, and is used for building. The soil is derived from the debris of the granite; is said to absorb and retain water eagerly. In some parts, as at Kandy, there is crystalline limestone.

Climate.—This differs, of course, exceedingly at different elevations. At Colombo, sea-level, the climate is warm, equable, and limited. Mean annual temperature about 81°. Mean temperature—April, 82°·70; January, 78°·19; amplitude of the yearly fluctuation = 4°·51. April and May are the hottest months; January and December the coldest. Amount of rain about 74 inches; the greatest amount falls in May with the S.W. monsoon (about 13 to 14 inches); and again in October and November with the N.E. monsoon (about 10 to 12 inches) in each month. Rain, however, falls in every month, the smallest amount being in February and March. The heaviest yearly fall ever noted was 120 inches. The humidity is very great, about the same as at Jamaica. The S.W. monsoon blows from May to September, and the N.E. monsoon during the remainder of the year, being unsteady and rather diverted from its course (long-shore wind) in February and March.

At Kandy (72 miles from Colombo, 1676 feet above sea-level), the mean temperature is less, 3° to 5°; the air is still absolutely humid, though relatively rather dry. At 9.30 A.M. the mean annual dew-point is 70°·4, and at 3.30 P.M. it is 71°·54. This corresponds to 8·11 and 8·42 grains in a cubic foot of air; as the mean temperature at these times is 76·37 and 79·27, the mean annual relative humidity of the air at 9.30 A.M. and 3.30 P.M. is 71 and 63 per cent. of saturation. The heat is oppressive, as Kandy lies in a hollow, as in the bottom of a cup.

* For a full account, see Sir E. Tennant's Ceylon.

At Newera Ellia (48 miles from Kandy, and 6210 feet high) is a large table-land, where, since 1828, some Europeans have been stationed; the climate is European, and at times wintry; the thermometer has been as low as 29°, and white frosts may occur in the early morning in the coldest months. The mean annual temperature is about 59°.*

In the dry season (January to May) the thermometer's daily range is excessive; the thermometer may stand at 29° at daybreak, and at 8 A.M. reach 62°; at mid-day it will mark 70° to 74°, and then fall to 50° at dark. In one day the range has been from 27° to 74° = 47°. The air is very dry, the difference between the dry and wet bulbs being sometimes 15°. Assuming the dry bulb to mark 70°, this will give a relative humidity of only 38 per cent. of saturation; the barometer stands at about 24·25 inches. Although the diurnal range of temperature is thus so great, it is equable from day to day.

Such a climate, with its bright sun and rarefied air, an almost constant breeze, and an immense evaporating force, seems to give us, at this period, the very beau ideal of a mountain climate.

In the wet season (May or June to November) all these conditions are reversed. The mean thermometer of 24 hours is about 59°, and the range is only from 56° at daybreak to 62° at mid-day; during the height of the monsoon, there are about 30 inches of rainfall, and sometimes as much as 70; the air is often almost saturated.

Two more striking climatic differences than between January and June can hardly be conceived, yet it is said Newera Ellia is equally healthy in the wet as in the dry season; the human frame seems to accommodate itself to these great vicissitudes without difficulty. The most unhealthy times are at the changes of the monsoons.

Although there is some moist and even marshy ground near the station, ague is not common, though it is seen; the temperature is too low in the dry season, and the fall of rain too great in the wet. Typhoid fever is seen, and may be combined with periodic fever (Massy, in Army Med. Reports, vol. viii. p. 499). It is said that dyspepsia, hepatic affections, and nervous affections are much benefited; phthsis to some extent, but, it would appear, scarcely so much as European experience would have led us to expect; rheumatism does not do well, nor, it is said, chronic dysentery; but it would be very desirable to test this point as well as that of the influence on phthisis carefully. The so-called "hill diarrhœa" of India prevailed in 1865, though before this it was unknown. Dysentery sometimes prevailed, and is caused in some cases by bad water (Massy).

The soil of Newera Ellia is chiefly decomposed gneiss; it is described by Dr Massy as being as hygroscopic as a sponge; the contents of cesspools easily traverse it, and the removal of excreta demands great care.

The neighbouring Horton Hills are said to be even better than Newera Ellia itself. Probably in the whole of Hindustan, a better sanitary station does not exist. It is inferior, if it be inferior, only to the Neilgherries, and one or two of the best Himalayan stations.

Diseases of the Native Population.

In some parts of the island, especially at Trincomalee, there is much malarious disease, and hepatic and splenic engorgements are common; dysentery, diarrhœa, rheumatism, and skin diseases are all common. At Colombo.

* I have taken many of these facts from an excellent Report by Assistant-Surgeon R.A. Allan, which I had the advantage of reading, as well as from Sir E. Tennant's book.

smallpox, cholera, and continued fevers are frequent. The sanitary condition of Colombo is bad; the native town is badly drained; there are many cess-pools, and wells close to them.

Elephantiasis and leprosy are common in some parts, scarcely seen in other (Trincomalee). At Trincomalee, Dr Kelaart states that scrofula is very common, and is attributed by the natives to syphilis introduced by the Portuguese, and kept up by intermarriage.

In the district of Kandy the population would seem to be healthier; in 1859 the deaths were 20·27 per 1000 living, and the births 24·93.* If this be true for all years, it contrasts favourably even with England.

Diseases of the Troops.

In Ceylon, as in so many other stations, we find that the amount of sickness and mortality has greatly declined of late years. In the earlier periods it was very great. Destructive fevers (malarious? typhoid? bilious remittent?) of uncertain nature prevailed, and in some years, as in 1817, were very fatal. Liver diseases (often attended with abscess) have always been much more common at Colombo and Trincomalee than at Kingston or Port-Royal in Jamaica, with the same high annual temperature and the same equability of climate.

Dysentery and diarrhœa have also always been frequent, and are still so. In fact, the diseases of troops are very similar to those of Hindustan, except that, on the whole, there has been less fatality.

Per 1000 *of Strength* (*White Troops*).

Years.	Loss of Strength.			Loss of Service.		
	Deaths (all Causes.)	Deaths from Disease.	Invaliding.†	Admissions.	Mean daily Sick.	Days in Hospital to to each Sick Man.
1817–36,	69·8	...	...	1678	...	...
1837–56,	38·6	...	...	1407	...	...
1859–65,	26·50	24·74	59·06	1557·1	73·93	17·33
1866,	21·44	18·05	48·53	1328·5	58·69	16·13
1867,	14·15	...	...	1088·1	...	...

If these numbers be compared with the West Indian or Canadian stations, the great amount of sickness and mortality in Ceylon is evident. The loss of service is very serious.

When the causes of this great sickness and mortality are looked into, they are found to be as follows:—Paroxysmal fevers, continued fevers, dysentery, ophthalmia, enthetic diseases, acute and chronic hepatitis, acute and chronic bronchitis, drunkenness, phlegmon, and ulcers, give the largest admissions. Cholera, dysentery, hepatitis, and phthisis appear to be the chief causes of mortality. In the years 1864–66 the deaths from acute and chronic hepatitis were 9 out of a total of 67 deaths in the island, or 13·43 per cent of total deaths.

The diseases, in fact, are chiefly those of India.

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* MS. Report on Kandy, by Surgeon M'Gregor.

† By the term invaliding is implied the troops actually discharged the service for ill health.

The deaths from tubercular disease in Ceylon in the years 1859–66 were 2·97 per 1000 of strength. There is also some invaliding, though not much.

With regard to the lessening of this considerable amount of sickness, the measures necessary for India must be adopted in Ceylon. (See also chapter on PREVENTION OF DISEASE.)

Among the black troops in Ceylon (1859–65) the admissions have averaged 1061, and the deaths 15·45, or without violent deaths, 13·87 per 1000 of strength. In 1867 the total mortality was 11·3 per 1000. The chief causes of admissions are paroxysmal fevers, and of deaths, cholera, dysentery, and paroxysmal fevers. "Continued fever" also figures among the returns, but is less common of late years. The average number constantly sick is about 32, and the duration of the cases 10 or 11 days.

In Ceylon, therefore, the black troops are healthier than the white, contrasting in this remarkably with the West Indies.

In conclusion, it may be said that much sanitary work has evidently to be done in Ceylon before the state of the white troops can be considered at all satisfactory.

SECTION VIII.

INDIA*

More than 60,000 Europeans are now (1869) quartered in India, and there is in addition a large native army. In this place the Europeans will be chiefly referred to, as it would require a large work to consider properly the health of the native troops.†

In the First Book various points connected with the health of Europeans in India have been discussed; in this place I have merely to give a short outline of the conditions of service in that country, and of the amounts of sickness and mortality.

The 60,000 Europeans are thus distributed:—About 36,000 are serving in the Bengal Presidency, which includes Bengal proper, the North-West Provinces, the Punjab, and Trans-Indus stations. About 12,000 are serving in the Madras Presidency, which also garrisons some part of the coast of Burmah, and sends detachments of native troops to the Straits of Malacca. About

* No medical officer should serve in India without carefully studying one of the best works ever published on hygiene, Dr Norman Chevers' essay on the "Means of Preserving the Health of Europeans in India," published in the Indian Annals. It is to be regretted that it has not been issued as a separate work. The Introduction to Sir Ranald Martin's great work on "Tropical Diseases" contains most valuable sanitary rules, and his papers lately published in the Lancet (1868) on the Sanitary History of the Army in India, are very instructive. Dr Moore's "Health in the Tropics" is also a work all should read. I need not say that the Report of the Indian Sanitary Commission should be very carefully considered. The Government have published in a small form the Report of the Indian Sanitary Commission, and an Abstract of all the Station Returns sent in to the Commission, with some of the evidence, and this will be a most valuable document for all officers serving in India. The present chapter may perhaps serve as a sort of introduction to this larger work. The Barrack Improvement Commissioners have also published a very useful work, entitled "Suggestions in Regard to Sanitary Works for Indian Stations." Deputy-Inspector Dr Charles Gordon, C.B., has published a series of papers on the Early Progress of Army Sanitation in India (Medical Times and Gazette, 1868–69), which, it is to be hoped, will appear in a permanent form.

† The general principles of hygiene are of course to be applied in the case of the natives of Hindustan, and so far there is nothing unusual. In the chapter on FOOD I have purposely included the chief articles of diet; the question of water and air is the same for all nations, and other hygienic rules of clothing or exercise can be easily applied to them. But their health is much influenced by their customs, which are in many races peculiar. The only proper way of treating such a subject would be by a work on the hygiene of India generally, including the native army as a branch of the community.

12,000 are serving in the Bombay Presidency.* The troops consist of all arms.

These men are serving in a country which includes nearly 28° of lat. and 33° of long., and in which the British possessions amount to 1,465,322 square miles. Stretching from within 8° of the equator to 15° beyond the line of the tropics, and embracing countries of every elevation, the climate of Hindustan presents almost every variety; and the troops serving in it, and moving from place to place, are in turn exposed to remarkable differences of temperature, degrees of atmospheric humidity, pressure of air, and kind and force of wind, &c.

Watered by great rivers which have brought down from the high lands vast deposits in the course of ages, a considerable portion of the surface of the extensive plains is formed by alluvial deposit, which, under the heat of the sun, renders vast districts more or less malarious; and there are certain parts of the country where the development of malaria is probably as intense as in any part of the world. A population, in some places thickly clustered, in others greatly scattered, formed of many races and speaking many tongues, and with remarkable diverse customs, inhabits the country, and indirectly affects very greatly the health of the Europeans.

Cantoned over this country, the soldiers are also subjected to the special influences of their barrack life, and to the peculiar habits which tropical service produces.

We can divide the causes which act on the European force into four sub-sections:—

1. The country and climate.
2. The diseases of the natives.
3. The special hygienic conditions under which the soldier is placed.
4. The service, and the individual habits of the soldier.

Sub-Section I.—The Country and Climate.

The geological structure and the meteorological conditions are, of course, extremely various, and it is impossible to do more than glance at a few of the chief points.

1. *Soil.*†—There is almost every variety of geological structure. In the north-west, the vast chain of the Himalayas is composed of high peaks of granite and gneiss; while lower down is gneiss and slate, and then sandstone and diluvial detritus. Stretching from Cape Comorin almost to Guzerat, come the great Western Ghauts, formed chiefly of granite, with volcanic rocks around; and then stretching from these, come the Vindhya and Satpoora Mountains, which are chiefly volcanic, and enclose the two great basins of the Taptee and Nerbudda rivers. Joining on to the Vindhya, come the Aravalli Hills, stretching towards Delhi, and having at their highest point Mount Aboo, which is probably destined to become the great health resort of Central India.

On the east side, the lower chain of the Eastern Ghauts slopes into the table-land of the Deccan; and at the junction of the Eastern and Western Ghauts come the Neilgherry Hills, from 8000 to 9000 feet above sea-level, and formed of granite, syenite, hornblende, and gneiss. But to enumerate all the Indian mountains would be impossible.

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* For brevity, it is customary to speak of serving in Bengal, Bombay, or Madras, when speaking of the Presidency, so that these names are sometimes applied to the cities, sometimes to the presidencies; but a little care will always distinguish which is meant.

† See Carter's "Summary of the Geology of India," in the "Journal of the Bombay Asiatic Society Transactions," 1853.

Speaking in very general terms, the soil of many of the plains may be classed under four great headings.

(a.) Alluvial soil, brought down by the great rivers Ganges, Indus, Brahmapootra, rivers of Nerbudda, Guzerat, &c. It is supposed that about one-third of all Hindustan is composed of this alluvium, which is chiefly siliceous, with some alumina and iron. At points it is very stiff with clay—as in some parts of the Punjab, in Scinde, and in some portion of Lower Bengal. Underneath the alluvial soil lies, in many places, the so-called clayey laterite. Many of the stations in Bengal are placed on alluvial soil.

This alluvial soil, especially when, not far from the surface, clayey laterite is found, is often malarious; sometimes it is moist only a foot or two from the surface; and, if not covered by vegetation, is extremely hot.

As a rule, troops should not be located on it. Whatever be done to the spot itself—and much good may be done by efficient draining—the influences of the surrounding country cannot be obviated. Europeans can never be entirely free from the influences of malaria. There is but one perfect remedy: to lessen the force in the plains to the smallest number consistent with military conditions, and to place the rest of the men on the higher lands.

Somewhat different from the alluvial is the soil of certain districts, such as the vast Runn of Cutch, which have been the beds of inland seas, and now form immense level marshy tracks, which are extremely malarious. The Runn of Cutch contains 7000 square miles of such country.

(b.) The so-called "regur," or "cotton soil," formed by disintegrated basalt and trap, stretches down from Bundelcund nearly to the south of the peninsula, and spreads over the table-land of Mysore, and is common in the Deccan. It is often, but not always, dark in colour. It contains little vegetable organic matter (1·5 to 2·5 per cent.), and is chiefly made up of sand (70 to 80 per cent)., carbonate of lime (10 to 20 per cent.), and a little alumina. It is very absorbent of water, and is generally thought unhealthy. It is not so malarious as the alluvium, but attacks of cholera have been supposed to be particularly frequent over this soil.

(c.) Red soil from disintegration of granite. This is sometimes loamy, at other times clayey, especially where felspar is abundant. The clay is often very stiff.

(d.) Calcareous and other soils scattered over the surface, or lying beneath the alluvium or cotton soil. There are, in many parts of India, large masses of calcareous (carbonate of lime) conglomerate, which is called kunkur. It is much used in Bengal for footpaths and pavements.

In Behar, and some other places, the soil contains large quantities of nitre, and various of the sand plains are largely impregnated with salts.

2. *Temperature.*—There is an immense variety of temperature. Towards the south, and on the sea-coast, the climate is often equable and uniform. The amplitudes of the annual and diurnal fluctuations are small, and in some places, especially those which lie somewhat out of the force of the south-west monsoon, the climate is perhaps the most equable in the world.

At some stations on the southern coast, the temperature at the sun's zenith is lower than at the declination, in consequence of the occurrence of clouds and rain, brought up by the south-west monsoon.

In the interior, on the plateaux of low elevation, the temperature is greater, and the yearly and diurnal fluctuations are more marked. On the hill stations (6000 to 8000 feet above sea-level), the mean temperature is much less; the fluctuations are sometimes great, sometimes inconsiderable.

The influence of winds is very great on the temperature; the sea winds lowering it, hot land winds raising it greatly.

The temperature of a few of the principal stations is subjoined, merely to

give an idea of the amount of heat in different parts of the country.* Those of the hill stations are given under the proper headings.

Mean Temperature and Height, above Sea-level, of some of the larger Stations.

Bengal Presidency.

Months.	Calcutta, Fort-William, 8 feet above sea-level.	Benares, 270 feet above sea-level.	Cawnpore, 500 feet above sea-level.	Lucknow, 360 feet above sea-level.	Meerut, 900 feet above sea-level.	Ferozepore, 720 feet above sea-level.	Punjab, generally 800 to 900 feet above sea-level.	Peshawur, 1056 feet above sea-level.
Mean of year,	82°	78°	80·4°	79°	77°	78°	73°	74°
January,	70	66	64	66	61	59	54	52
February,	75	69	70	68	65	68	60	55
March,	83	75	72	79	70	76	68	65
April,	88	84	89	88	83	81	77	75
May,	89	93	97	91	90	94	86	88
June,	87	88	91	90	92	95	89	91
July,	85	86	87	88	88	90	87	91
August,	85	82	87	84	84	86	86	88
September,	85	83	85	85	82	86	83	84
October,	84	79	79	79	76	79	76	73
November,	78	70	75	70	68	68	61	64
December,	72	64	68	60	62	58	55	56
Amplitude of yearly fluctuation (difference between hottest and coldest months),	19	29	33	31	31	37	35	39

Madras Presidency.

Months.	Madras, Fort St George, at sea-level.	Bangalore, 3000 feet above sea-level, 1 year only.	Bellary, 1500 feet above sea-level.	Secunderabad, 1800 feet above sea-level.	Cannanore, 15 feet above sea-level.
Mean of year,	82°	76°	80°	80°	82°
January,	76	69	74	73	82
February,	78	73	79	76	82
March,	80	79	85	81	84
April,	84	79	88	86	86
May,	87	82	86	89	85
June,	88	77	83	83	80
July,	85	77	80	80	79
August,	85	75	79	79	79
September,	84	76	79	78	79
October,	82	75	78	78	81
November,	79	73	74	76	82
December,	76	71	73	73	81
Amplitude of yearly fluctuation,	12	13	15	16	7

* These are taken from Mr Glaisher's very excellent report in the Indian Sanitary Commission, which must be consulted for fuller details of the greatest value.

The increase in the amplitude of the yearly fluctuation is thus seen as we pass to the north, and ascend above sea-level.

Bombay Presidency.

Months.	Bombay, at sea-level.	Poonah, 1800 feet above sea-level.	Belgaum, 2260 feet above sea-level.	Nagpore.	Neemuch, 1 year.	Mhow, 1862 feet above sea-level.	Hyderabad (Scinde), 99 feet above sea-level.	Kurrachee, 27 feet above sea-level.
Mean of year,	80°	78°	74°	81°	71°	77°	81°	78°
January, .	74	72	72	71	55	70	64	62
February, .	76	75	75	75	60	72	71	67
March, . .	80	79	78	84	70	80	81	74
April, . .	83	83	81	93	81	86	87	84
May, . .	86	85	78	93	84	87	91	84
June, . .	83	81	75	86	80	74	92	88
July, . .	81	77	73	81	74	82	91	88
August, .	81	76	72	81	74	75	88	82
September,	80	77	74	82	75	75	85	81
October, .	82	79	74	82	71	77	82	79
November,	79	76	72	75	67	75	73	73
December, .	76	73	70	73	65	71	66	65
Amplitude of yearly fluctuation, .	12	13	11	22	29	17	28	26

These temperatures, which represent those of stations where the troops are placed, should be compared with the temperature of hill stations subsequently given.

In several places there are great undulations of temperature from hot land winds, or from sea or shore breezes, or from mountain currents, which give to the place local peculiarities of temperature.

The temperature of the sun's rays has not yet been properly determined with the self-registering black-bulb thermometer in vacuo. The temperatures which are recorded are, I believe, all made with the common thermometer, and give no adequate idea of the real heat of the sun.

These few figures give a general view of the chief thermometric points. Many of these stations are marked by a continued high temperature and a small mean daily range. To get the same mean annual temperature as in England, it would be necessary that 9500 feet be ascended in places south of lat. 20°; between lat. 20° and 26°, 9000 feet; between lat. 26° and 30°, 8700 feet; and north of lat. 30°, 8500.

The mean monthly temperatures would, however, at such elevations, differ somewhat from those of England. Speaking generally, an elevation of 5000 to 6000 feet will give over the whole of India a mean annual temperature about 10° higher than that of England, and with a rather smaller range.

Mr Glaisher has calculated that in the cold months the decrease of temperature is 1°·05 for each 300 feet of ascent, but increases from March to August to 4°·5, and then gradually declines. These results are not accordant with the recent balloon ascents in this climate.

Humidity.—The humidity of different parts of India varies extremely; there are climates of extreme humidity—either flat, hot plains, like Lower Scinde, where, without rain, the hot air is frequently almost saturated, and may contain 10 or 11 grains of vapour in a cubic foot; or mountain ranges like Dodabetta, in Madras, 8640 feet above sea-level, where, during the rainy season, the air is also almost saturated; a copious rain, at certain times of the year, may make the air excessively moist, as on the Malabar coast, the coast of Tenasserim, or on the Khasyah Hills, where the south-west monsoon parts with its vapours in enormous quantities.

On the other hand, on the elevated table-land of the interior, and on the hot plains of North-West India, during the dry season, or in the places exposed to the land winds at any part, the air is excessively dry. In the Deccan the annual average of the relative humidity is only 55 per cent. of saturation (Sykes). Mr Glaisher has assembled all that is at present known on the humidity of India. I extract a few stations:—

Mean Dew-Point.

Months.	Calcutta, Fort-William.	Madras, Fort St George.	Bombay.	Benares.	Meerut.	Peshawur.	Bellary.	Secunderabad.	Poonah.	Kurrachee.	Belgaum.
	°	°	°	°	°	°	°	°	°	°	°
January,	57	67	64	48	54	39	54	54	51	48	54
February,	61	68	64	53	56	43	60	51	50	55	51
March,	68	71	68	57	59	56	58	60	54	60	58
April,	72	76	73	60	56	66	69	59	59	66	60
May,	76	76	75	72	71	62	62	62	65	74	66
June,	78	73	76	78	76	72	69	66	67	76	68
July,	78	73	76	84	80	74	69	68	69	76	68
August,	78	74	74	80	71	74	66	71	69	75	67
September,	78	75	75	80	75	65	59	73	67	71	66
October,	74	74	74	76	71	56	67	66	62	66	61
November,	64	71	67	61	61	45	66	58	55	52	61
December,	57	69	64	54	48	39	60	54	51	47	55
Mean daily average of Year,	70	72	71	67	65	57	63	62	59	64	61

If the table at page 438 be looked at, the mean monthly amount of vapour in a cubic foot of air will be the number opposite the mean dew-point in the above table. If the mean monthly temperature of the month at any of the above stations be taken out of the table of mean monthly temperature already given, the mean monthly relative humidity (or, in other words, the evaporating force of the air) can be calculated.

Thus, let us take the month of July at Calcutta:—

Mean dew-point = 78 = 10·31 grains of vapour in a cubic foot of air.
Mean temperature = 85 = 12·78 grains of vapour in a cubic foot of air.

The relative humidity $\frac{10{\cdot}31 \times 100}{12{\cdot}78} = 80$ per cent. of saturation. (See METEOROLOGY).

It may be well to mention the dew-point of the year at Greenwich for comparison; it is 44°; the mean weight of vapour is 3·3, varying from 4·7 grains in August to 2·4 in January; the mean relative humidity is 82, varying from 89 in December and January to 76 in July. Calcutta, therefore, with a mean yearly humidity of 68·6 per cent. of saturation, is, as far as relative humidity (*i.e.*, evaporating power) goes, less moist than England, and the evaporating power is also increased by the higher temperature.

Rain.—The amount of rain and the period of fall vary exceedingly in the different places. It is chiefly regulated by the monsoons.

When the south-west monsoon, loaded with vapour, first strikes on high land, as on the Western Ghauts, on the Malabar coast, or on the mountains of Tenasserim, and especially on the mountains of the Khasyah Hills, at some points of which it meets with a still colder air, a deluge of rain falls; as, for example, at Cannanore (Malabar), 121 inches; Mahableshwur, 253 inches; Moulmein (Tenasserim), 180 inches; Cherrapoonjee (Khasyah Hills), 600 inches. On the other hand, even in places near the sea, if there is no high land, and the temperature is high, scarcely any rain falls; as in Aden, on the south coast of Arabia, or at Kotu, in Scinde, where the amount is only 1·8 annually, or Kurrachee, where the yearly average is only 4·6 inches. Or in inland districts, the south-west monsoon, having lost most of its water as it passed over the hills, may be comparatively dry, as at Nusseerabad, where only 15·8 inches fall per annum, or Peshawur, where there are 13·7 inches annually.

The yearly amount of rain in some of the principal stations is—

	Average.		Average.
Calcutta,	56·8	Madras Presidency—	
Madras,	50	Bellary,	21·7
Bombay,	72·7	Bangalore,	25
Bengal Presidency—		Trichinopoly,	30·6
Dinapore,	31·1	Secunderabad,	34·6
Berhampore,	49·8		
Benares,	37·4		
Ghazeepore,	41·4	Bombay Presidency—	
Azimghur,	40	Belgaum,	51·5
Agra,	27·9	Poonah,	27·6
Delhi,	25·1	Neemuch,	34·1
Meerut,	18	Kamptee,	41·8
Punjab,	56·6		

Winds.—The general winds of India are the north-east monsoon, which is, in fact, the great north-east trade-wind, and the south-west monsoon, a wind caused by the aspiration of the hot earth of the continent of Asia, when the sun is at its northern declination. During part of the year (May to August) the south-west monsoon forces back the trade-wind or throws it up, for at great altitudes the north-east monsoon blows through the whole year, and the south-west monsoon is below it. But, in addition, there are an immense number of local winds which are caused by the diverting effect of hills on the monsoons, or are cold currents from hills, or sea breezes, or shore winds caused by the contact of sea breezes and other winds, or by the first feeble action of the south-west monsoon before it has completely driven back the north-east trade. The south-west monsoon is in most of its course loaded with vapour; the north-east is, on the contrary, a colder and drier wind, except when at certain times of the year, in passing over the Indian Ocean, it takes up some water, and reaches the Coromandel Coast and Ceylon a moist and rain-carrying wind.

The hot land winds are caused by both the south-west monsoon, after it has parted with its moisture and got warmed by the hot central plains, and the north-east monsoon; the temperature is very great, and the relative humidity very small; the difference between the dry and the wet bulb being sometimes 15° to 25° Fahr.

Pressure of the Air.—On this point little need be said. The barometer is very steady at most sea-coast stations, and its daily variations (see METEOROLOGY) are chiefly caused by alteration in humidity. An elevation of 5000 feet lowers the barometer to nearly 25 inches.

Electricity.—On this point few, if any, experiments have been made; the air is extremely charged with electricity, especially in the dry season, and the dust-storms are attended with marked disturbance of the electrometer.*

The estimation of the effects of such various climates is a task of great difficulty. Long-continued high temperature, alternations of great atmospheric dryness and moisture, rapidly moving and perhaps dry and hot air, are common conditions at many stations; at others, great heat during part of the year is followed by weather so cold that even in England it would be thought keen. When to these influences the development of malaria is added, enough has been said to show that, *a priori*, we can feel certain that the natives of temperate climates will not support such a climate without influence on health, and the selection of healthy spots for troops is a matter of the greatest moment as affects both health and comfort. This much being said, it must at the same time be asserted that, malaria excepted, the influences of climate are not the chief causes of sickness.

The location of troops should be governed by two or three conditions—1. Military necessities; 2. Convenience; 3. Conditions of health. The second of these conditions is, however, a mere question of administration; every place can be made convenient in these days of railways and easy locomotion. Military necessity and health are the only real considerations which should guide our choice.

What is now wanted in India is some great soldier, who, with the intuitive glance of genius, will indicate what are the vital military points. These must be held with the necessary forces, and then the whole of the remaining troops can be located on the most healthy spots.

These spots cannot be in the plains. Let any one look at a geological map of India, and see the vast tract of alluvial soil which stretches from the loose soil of Calcutta, formed by the deposit of a tidal estuary, up past Cawnpore, Delhi, to the vast plains of the Punjab, Scinde, and Beloochistan. The whole of that space is more or less malarious, and will continue to be so until, in the course of centuries, it is brought into complete tillage, drained, and cultivated.

In looking for healthy spots, where temperature is less tropical, and malarious exhalations less abundant, there are only two classes of localities which can be chosen—seaside places and highlands.

Seaside places.—The advantages of a locality of this kind are, the reduction in temperature caused by the expanse of water, the absence of excessive dryness of the air, and the frequent occurrence of breezes from the sea. All these advantages may be counteracted by the other features of the place; by a damp alluvial soil, bad water, &c.

It does not appear that many eligible places have yet been found, and as a substitute in Bengal, the Europeans from Calcutta go and live on board a

* See Baddeley's "Whirlwinds and Dust-storms of India" (1860), for a very good account of these singular storms.

steamer anchored off the Sandheads, thus literally carrying out a suggestion of Lind in the West Indies a century ago.

In the Bay of Bengal, Waltair, in the northern division of Madras, is one of the best.* Cape Calimere (28 miles south of Nagapatam) also appears to have many advantages (Macpherson). On the opposite coast, Cape Negrais on the Burmese coast, was pointed out as long ago as 1825, by Sir Ranald Martin as a good marine sanitarium, and Amherst in Tenasserim, and some of the islands down the coast towards Mergui, are beautiful spots for such a purpose, being, however, unfortunately, at a great distance from the large military stations, and not being well supplied with food.

On the Bombay side, at Sedashagur or Beitkul Bay, between Mangalore and Goa, a spur of the Western Ghauts projects into the sea for upwards of a mile, and forms an admirable sea-coast sanitarium (Macpherson).

All these sea-coast stations seem adapted for organic visceral affections and dysentery, but they are not so well calculated for permanent stations for healthy men. Probably they are rather sanitaria than stations.

Highlands.—The location of troops on the hills or on elevated table-lands has long been considered by the best army medical officers as the most important sanitary measure which can be adopted. Not only does such a location improve greatly the vigour of the men, who on the hill stations preserve the healthy, ruddy hue of the European, but it prevents many diseases. If properly selected, the vast class of malarious diseases disappears; liver diseases are less common, and bowel complaints, in some stations at any rate, are neither so frequent nor so violent. Digestion and blood-nutrition are greatly improved. Moreover, a proper degree of exercise can be taken, and the best personal hygienic rules easily observed.

Indian surgeons appear, however, to think the hill stations not adapted for cardiac and respiratory complaints; it is possible that this objection is theoretical. The latest European experience is to the effect that phthisis is singularly benefited by even moderate, still more perhaps by great elevation; that anæmia and faulty blood-nutrition are cured by high positions with great rapidity, and that if the elevation be not too great (perhaps not over 3000 feet) even chronic heart diseases are improved. In some of the hill stations of India bowel complaints were formerly so frequent as to give rise to the term "hill diarrhœa." The elevation was credited with an effect which it never produced, for, not to speak of other parts of the world, there are stations in India itself (Darjeeling, for example) as high as any other, where the so-called hill diarrhœa was unknown. At Newera Ellia, in Ceylon, too, if the simple condition of mountain elevation could have produced diarrhœa, it would have been present. The cause of the hill diarrhœa was certainly, in many stations, the impure drinking water; whether this was the case in all, I am not sure. Some of the hill stations are said not to be adapted for rheumatic cases; in other instances (as at Subathoo) rheumatism is much benefited. I infer, from reading the reports from these stations, that damp barracks, and not the station, have been in some cases the cause of the rheumatism.

But it must be noticed that the evidence given before the Indian Sanitary Commission shows, on all or almost all hill stations, a most lamentable want of the commonest sanitary appliances. At great expense men are sent up to the hills, where everything is, or was, left undone which could make that expense profitable. It appeared to be thought sufficient to ascend 6000 feet to abandon all the most obvious sanitary rules, without which no place can be healthy.

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* Evidence of Dr Maclean in Indian Report, p. 139.

Admitting, as a point now amply proved, that stations of elevation are the proper localities for all troops not detained in the plains by imperative military reasons, the following questions are still not completely answered :—

1. What amount of elevation is the best? We have seen that to reduce the temperature to the English mean, 5000 to 6000 feet must on an average be ascended. But then such an elevation brings with it certain inconveniences, viz., in some stations much rain and even fog at certain times of the year, and cold winds. However unpleasant this may be, it yet seems clear, from the experience of Newera Ellia, in Ceylon, that damp and cold are not hurtful. But it must also be said that, with a proper selection, dry localities can be found at this elevation.

From 3000 to 4000 feet have been recommended, especially, to avoid the conditions just mentioned. Whether places of this height are equal in salubrity to the colder and higher points is uncertain.

Even at 6000 feet there may be marsh land, though it is not very malarious. Malarious fever has been known during the rains at Kussowlie (6400 feet), and Subathoo (4000), and other Himalayan stations. Malaria may, however, drift up valleys to a great height;* but, apart from this, it seems likely that 5000 feet, and probably 4000, will perfectly secure from malaria. Probably, indeed, a less height will be found effectual.

At no point do hot land winds occur, or at any rate endure, at above 4000 feet.

On the whole, it would appear probable that the best localities are above 5000 feet, but below 7000.

2. What stations are the best—the tops of solitary hills, spurs of high mountains, or elevated table-lands?

Ranald Martin has called especial attention to the solitary hills, rising as they do sometimes from an almost level plain to 2000 and 3000 feet. Such mountain islands seem especially adapted for troops if there is sufficient space at the top. They are free from ravines conducting cold air from higher land, and are often less rainy than the spurs of loftier hills.

The spurs of the Himalayas, however, present many eligible spots, and so do some table-lands. And, perhaps, on the whole, if the elevation is sufficient, it is not a matter of much importance which of these formations is chosen; other circumstances, viz., purity of water, space, ease of access, and supplies, &c., will generally decide.

In choosing hill stations, the points discussed in the chapter on Soils should be carefully considered, and it is always desirable to have a trial for a year or two before the station is permanently fixed.

It may be desirable to give an enumeration of the hill stations now in use. The following table is copied from the work of the late Dr Macpherson.

In all the presidencies of India elevated spots where troops can be cantoned exist in abundance.†

Fresh stations are, however, being constantly discovered, and it seems now

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* It has drifted up even to the summits of the Neilgherries, 7000 or 8000 feet.—*Indian Sanitary Report*, Mr Elliott's Evidence, vol. i. p. 250.

† See the evidence in the Indian Sanitary Report (vol. i.) of Sir R. Martin, Mr Elliott, Dr Maclean, Dr Alexander Grant, Mr Montgomery Martin, and others. Also most instructive reports by Mr Macpherson, Indian Report, vol. ii. p. 622, and by Dr Alexander Grant, Indian Annals. On the location of troops I may also refer to Inspector-General Dr Beatson's very decided opinion on the necessity of placing on the hills all the men who can be spared from the military posts in the plains. No more valuable opinion could be given on such a point than that of an officer who has had the largest possible experience, and the best opportunities of forming a correct judgment. (See his Report in the Army Med. Report, vol. viii. p. 347.)

Names of Hill Stations.			Mean Temperature outside in Shade. January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Ascertained greatest Elevation.	Average Fall of Rain in Inches.
Bengal Presidency.	Darjeeling,		40	41	51	55	61	62	63	64	63	55	50	44	8000	132
	Simla,		40	44	53	61	66	80	75	78	70	67	52	46	8000	70
	Landour,		35	40	51	...	...	...	...	68	64	49	46	46	7300	...
	Murree,		...	...	...	...	...	69	68	66	62	62	...	...	6786	...
	Kussowlie,		42	47	58	64	77	73	70	70	72	66	...	...	6400	70
	Nynee Tal,		42	46	56	61	69	69	67	69	65	61	50	47	6200	83
	Dugshai,		42	47	57	64	69	71	72	68	66	62	54	53	6000	70
	Subathoo,		...	...	...	77	81	84	79	77	...	...	...	...	4000	70
Madras Presidency.	Ootacamund,	Neil-gherry range.	54	56	60	61	61	57	63	63	63	56	54	53	7361	60
	Kotagherry,	Neil-gherry range.	59	60	61	63	63	64	65	65	64	62	60	59	6100	55
	Wellington,	Neil-gherry range.	59	61	67	68	68	64	70	70	70	63	61	60	5840	50
	Coonoor,	Neil-gherry range.	60	62	68	68	68	65	70	70	70	65	62	62	5161	50
	Pulneys,		51	53	60	61	...	...	...	...	...	...	...	...	7000	...
	Mercara,		53	56	61	64	44	66	65	65	64	65	63	56	4500	100
	Annamullays,		...	...	...	...	...	...	...	...	66	56	...	...	6800	...
	Shevaroys,		65	65	68	71	71	68	68	68	67	66	66	65	5260	40
	Ramandroog,		70	76	80	80	75	73	71	70	70	71	71	67	3400	46
	Checuldah,		60	60	70	83	83	71	...	...	...	...	71	71	3600	...
	Sindwarrah,		An average of 8° lower than the station of Kamptee.													
	Muthoor,		Do. 11° do. do.													
Bombay Presidency.	Mahableshwur,		63	65	72	74	72	67	63	64	64	66	64	63	4700	240
	Poorandhur,		67	73	77	78	73	70	67	65	67	71	69	64	4200	73
	Mount Aboo,		61	61	79	77	77	77	69	69	69	69	69	71	4015	79

certain that there is scarcely any important strategical point without an elevated site near it.

Near Nynee Tal, in Kumaon, are Almorah (5500 feet), and Hawalbagh (4000 feet), both well spoken of. Kunawar (5000 or 6000 feet), in the valley of the Sutlej, has a delicious climate; and Chini (about 100 miles from Simla), is a most desirable spot.

Passing down from the north-west towards Calcutta, Dr M'Clellan found elevated land within 100 miles of Allahabad; and farther south still there came the Travancore mountains, with numerous good sites.

If, then, the mass of the troops are cantoned on elevated places, the disadvantages of climate are almost removed. The Indian Sanitary Commissioners recommend that one-third of the force shall be in the hills, and that enfeebled men and recruits especially shall be sent there. But it is to be hoped that not only one-third, but a large majority of the troops will eventually be placed there.

Sub-Section II.—Diseases of the Natives.

It is impossible that Europeans can be perfectly isolated from the nations among whom they serve; they have suffered from the pestilential diseases of the Hindus, but still it is wonderful that they have not suffered more. Cholera is the chief disease, which, arising in the native population, scourges their conquerors. Some fevers also, relapsing fever, perhaps a "febris icterodes," or bilious remittent, which has occasionally attacked Europeans, have had their origin, or at any rate their conditions of spread, in the dense populations of native cities. Happily, the Black Death (the Maha murree, or Pali plague) has never yet spread to the troops, and has indeed been confined within narrow limits. Still these pestilences among the native population are an ever-present menace to Europeans, and, as in the case of cholera, may pass to them at any time. Cholera, certainly, will never be extirpated until attacked in its strongholds, among the miserable dwellings which make so large a part of every oriental city.

In 1867 there were some cases among the troops of the contagious fever, which has caused so much mortality in many of the Bengal jails. The exact influence on Europeans of the customs and modes of life of the natives of India has not, as far as I know, been made an object of special study, but it cannot be inconsiderable. In many places the Europeans and the natives are in close neighbourhood, and the air at all times, and often the water, must be influenced by the social life of the native races. The proximity to large cities or bazaars is indeed often alluded to by army officers as influencing the health of their men; it would be very interesting to know the precise effect. The sanitary condition of almost all the large native towns, and the sanitary habits of the country people, are as bad as can be. Bad water, fœtid air, want of sewage removal, and personal habits of uncleanliness, abound everywhere. The Report of the Indian Sanitary Commission is now beginning a series of changes in this respect, which will probably change, *in toto*, the medical history of India.

Sub-Section III.—Special Hygienic Conditions.

The special hygienic conditions (apart from locality) under which the soldier serves in India have been the main causes of excess of disease. This subject has lately received a searching inquiry from the Sanitary Commissioners.* They declare, and after reading the Station Reports and the

* Report of the Commissioners on the Sanitary State of the Army in India, 1863. Report, p. 79, published in 1864 in small bulk.

evidence given before them, no one will doubt the assertion, that while malaria, extremes of temperature, moisture, and variability of temperature, cause a certain amount of sickness, "there are other causes of a very active kind, connected with stations, barracks, hospitals, and the habits of the men, of the same nature as those which are known in colder climates to occasion attacks of those very diseases from which the Indian army suffer so severely."

And the Commissioners enumerate a list of causes connected with unhealthy stations, bad barracks, overcrowding, impure air and water, bad drainage, imperfect ablution, inferior rations and cooking, &c.

In fact, no doubt can exist in the minds of all who have studied the subject, that these form the most potent class of causes which affect health.

Sub-Section IV.—Habits and Customs of the Troops.

The habits of the men and the customs of service were, however, also great causes of disease, and are still so to some extent.

The men were, as a rule, intemperate, great smokers, and indisposed for exertion. It has, indeed, been pointed out with truth, that in proportion to their amount of exercise the men were much overfed, and some diseases of the liver appear to result directly from this simple condition.

The want of exercise is not always the fault of the men. The early morning hours, and often the evening, are occupied with parades; in the period between, the men used to be confined to barracks, and are still sometimes so. Here, listless, unoccupied, and devoured with ennui, they passed the weary day, lying down perhaps for hours daily, or lounging on chairs smoking.

This forced confinement to barracks is indeed an evil often greater than that it is intended to remove. To prevent men from passing out into the sun they are compelled to remain in a hot, often ill-ventilated room, worse for health than the intensest rays of the sun,* that scape-goat of almost every fault and vice of Indian life.

All these causes have been summed up by Miss Nightingale in some of those telling sentences which have done more than anything else to force attention to these vital questions.†

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* I shall never forget the sufferings of the men in the old barracks at Madras. We arrived there from Moulmein, where the men had never been confined to barracks, and where, during two hot seasons, no injury had resulted from allowing them to go out when they liked. On arrival at Madras, in accordance with invariable custom, the men were confined to barracks. They lay all day on their beds, reeking with perspiration; the place was so small and ventilation so bad, that the heat was perfectly intolerable in the barracks, though the sun's rays were quite bearable. The sufferings were extreme. When the afternoon came, more injury had been done by the hot and impure air than exposure to the sun's rays could have caused.

At Moulmein, in Tenasserim, at one time, two European regiments served together. The barracks of each were perfectly healthy; the food and duties were the same; yet one showed a sick list and mortality always much greater than the other. Serving in the station shortly afterwards, I was so struck by this difference that I went over all the returns and reports in the staff-surgeon's office to make out the cause; the only difference I could detect was, that in the sickly regiment the men were confined to barracks, in the other they were allowed to go about as they pleased. Many years afterwards, I met with a medical officer who had served in the sickly regiment, and learned from him that he had always considered the confinement to barracks, and the want of exercise, and the impure air breathed by that system almost night and day, to have been the causes of a disparity so striking. No one would recommend imprudent exposure to the sun: men may be trusted to avoid its intensest rays; but to reduce men to enforced idleness for many hours, and to confine them in the small space of a barrack-room, is not the way of meeting the evil. (On this point see also page 580 for Dr Clark's observations on want of exercise as compared with exposure to the sun on the West Coast of Africa.) On this point, as in many others, the statements of Dr Kenneth Mackinnon are deserving of great attention. His remarks on the desirability of exercise, even in the trying climate of Tirhoot in Bengal, are very striking. (A Treatise on Public Health, by Kenneth Mackinnon, M.D., Cawnpore, 1848, pp. 27 and 145. He strongly recommended open sheds and gymnasia, and these are now being adopted.

† "How People may Live and not Die in India." By Florence Nightingale, 1863.

Of late years a great change has taken place in the habits of the men. More open air exercise of all kinds; and in the cooler stations athletic sports and cricket have been encouraged; in some of the hill stations the troops have been employed in making roads and public works, and the practice of trades has been promoted. Were the troops chiefly on the hills, as much exercise as at home would be possible, and the men would preserve their European vigour and appearance. But even in the plains exercise is necessary, and if it be taken at proper times (*i.e.*, with avoidance of the three or four hottest hours), and with proper precautions, such as keeping the head and spine well covered and cool, putting on after profuse sweating dry and thin mixed cotton and woollen underclothes, and protecting the loins and abdomen with a silk or flannel sash, and avoiding stimulants before and during the exercise, all men would be benefited even by very great exercise.

The pale, feeble appearance of persons who keep much in the darkened houses is really owing more to the absence of light and to the unhealthy and sedentary life than to the effect of the climate.

The subject of clothing has been already referred to. In Algeria, as in India, much good has been ascribed to the use of very large flannel belts, which the French suspend from the shoulders, a plan better adapted for comfort than the so-called cholera belts of India.

With regard especially to diet two points must be considered :—

1. What amount of food should be taken? In India, as in all parts of the world, food is taken in proportion to the mechanical work done by the body, and to the equivalent of mechanical force, viz., animal heat.

High temperature, as lessening the loss of the body heat, must, *pro tanto*, lessen the need of food to supply the temperature; and it has been supposed that the diet of men in cold countries (arctic regions) and in hot, contrasted remarkably in respect of the amount of carboniferous food taken by each. But although it is certain that large quantities of meat and fat are taken by men living in or arriving in cold countries, it is now known that the natives of some of the hottest parts of the world take immense quantities of both fats and starches. In fact, both these substances perhaps, certainly fats, are taken to supply mechanical force directly, as well as animal heat. It is not, in fact, yet known what amount of lessening of food, or what kind of lessening, the increased heat of the tropics demands, or whether any is demanded, for exact experiments are wanting. Our best guide at present for the quantity of food to be taken in the tropics, is to apportion it to the amount of mechanical work done, as in temperate climates. In India, as elsewhere, it must be in balance with exercise. The points then to be considered are the amounts of daily food and of daily exercise, and by means of the tables formerly given, and by knowing the habits of the men, little difficulty will be found in determining the proper ration quantity of food with accuracy.

Admitting that at present we are not in a position to say whether the relative proportions of the four great dietetic classes should be altered in India, from the standard proved to be the best for temperate climates, we can yet affirm that our present knowledge would seem to show that the amounts of these substances should not necessarily be altered.

The Indian regulation ration is as follows :—

Mutton is issued once a week; beef six times. Instead of rice, the soldier may, if he pleases, receive flour. Breakfast is at 8.30; dinner at 2.30; and tea after evening parade.

If this diet be compared with the home ratio, it is found to be slightly more nitrogenous and less rich in starches. The difference is not considerable, however. Is it too much for India? This will depend entirely on the

Daily Ration in India, in most Stations, in ounces and tenths of ounces.

Name of Article.	Daily Quantity.	Nutritive Value.				
		Water.	Nitrog. Subst.	Fats.	Starches.	Salts.
Bread, ...	16	6·4	1·28	·24	7·8	·2
Meat, ...	16, less 3·2 for bone, = 12·8	9·6	1·92	1·07	...	·2
Vegetables* taken as carrots,	16	13·6	·96	·04	·93	·11
Rice, ...	4	·4	·20	·03	3·33	·02
Sugar, ...	2·5	·075	...	...	2·41	·012
Salt, ...	1	...	...	...	...	1
Coffee (or in part black tea),	1·75	...	...	...	...	...
Total, exclusive of coffee, . . .	52·3	30·075	4·36	1·38	14·47	1·542
			Total Solids, 21·752†			

amount of exercise; no doubt for a perfectly idle man it would be too much, but not if the amount of exercise is that of the home standard. In fact, it is believed to be in reality insufficient in quantity and in quality, from the fact that good meat, and even in some parts good bread, is not readily procurable in India. Vegetables also are deficient in many stations at certain times of the year.‡ It appears, however, that the soldier almost always buys additional food, and he may eat much more than is stated above. Some years ago Dr Macnamara found the troops in Bengal taking no less than 76 ounces of food (*i.e.*, water-containing food), while the regulation ration is only 52 ounces, so that these men were largely over-feeding. And Dr Dempster (Indian Sanitary Report—Evidence) states that the majority of the recruits from Scotland and England eat in the hot weather in India much more animal food than in the coldest seasons in their native countries.§

It would therefore seem that illness may arise in India from excess of food, but it is not the regulation ration which produces it, but the additional purchased food, or the extreme idleness of the men, in which case even the regulation ration is too much. The only remedy is instruction of the men in what is good for them, and no men are so stupid as not to perceive what is best for their own comfort and happiness when it is once pointed out to them.

In addition, the soldier in India had till very lately the spirit ration (now lessened to one-half), which has the effect of lessening the power of appropriation of food, though not always the appetite, and thus indirectly may cause over-feeding.

* The vegetables are of different kinds: yams, sweet potatoes, pumpkins, &c. If yams are used, the amount is greater than in the text.

† In calculating out these diets, there is a little apparent loss from not carrying on all the places of decimals.

‡ Memorandum on Rations of Troops, by Dr C. A. Gordon, C.B. (Sanitary Commissioner for Bengal).

§ Colonel Sykes long ago directed particular attention to this point, stating, with perfect truth, that the soldier in India is over-stimulated by food and drink, and under-stimulated by bodily and mental exercise.

The amount of fat in the regulation ration is, as at home, too small ; but the soldier buys butter and other milk, and takes more oily food.

2. Admitting (till better observations are made) that men in the tropics, undergoing as much exertion as at home, will demand as much food, and in the same proportions, as far as the four classes of aliment are concerned (and it seems to me all physiological evidence shows that this must be the case, and that not external temperature, *per se*, but the work of the body, is the chief measure of food), the next question is, whether the different articles of the diet should be altered ; whether, for example, the same amount of nitrogen being given, it should be contained in vegetable or animal food?

It has been stated by several of the best observers in the tropics that those who eat largely of animal food are less healthy than those who take more vegetable food ; and Friedel, in his work on China, has lately again directed attention to the fact* that the amount of digestive and hepatic disease is much greater among the English than among any other European settlers in China. But whether this is owing to excessive animal food, or excess generally in all food, and to too much wine, beer, and spirits, is not certain. The diet is probably too rich as a whole.

Supposing meat is taken in proper but not excessive quantity with farinaceous food, as at home, is it less healthy than a quantity of vegetable food containing an equivalent amount of nitrogen? On this point it seems to me that strict scientific evidence has not been produced. With regard to excess of animal food there is no doubt ; but animal food in moderation has not, I think, been shown to be more active in causing liver complaints in India than at home.

Considering, indeed, how important it is, when the digestive organs have been accustomed to one sort of diet, not to suddenly and completely change it, it seems to me very doubtful whether it would be desirable for the European arriving in India at once to give up all previous habits, and to commence an entirely different kind of diet.

It is possible, however, that the meat standard of England might be somewhat reduced, and the bread, flour, and leguminosæ increased. This is not the opinion, however, of some of those who have lately paid particular attention to Indian rations (Dr C. A. Gordon and Dr Inglis†), and who believe that the amount of meat is even too small. Still the point is worthy of a careful trial, so that the question might be properly settled by the sole test of these matters, a sufficient experience. A certain number of men (one or two companies in a regiment) might be selected for these trials, and the state of health carefully noted.

It has often been said that Europeans in India should imitate the natives in their food, but this opinion is based (it seems to me) on a misconception. The use of ages has accustomed the Hindu to the custom of taking large quantities of rice, with pulses or corn ; put an European on this diet, and he could not at first digest it ; the very bulk would be too much for him. The Hindu, with this diet, is obliged to take large quantities of condiments (peppers, &c.) The European who did the same would produce acute gastric catarrh and hepatic congestion in a very short time ; in fact, as already stated, one great fault of the diet of Europeans arriving in India is too great use of this part of the native diet.

Two points about the diet of India seem quite clear. One is, that spirits are most hurtful, and that even wine and beer must be taken in great moderation.

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* Already noticed as regards India and the Mauritius.

† *Op. cit.* and Army Medical Report, vol. v. p. 380.

Of the two beverages, light wines (clarets), which are now happily coming into use in India for the officers, are the best. For the men good beer should be provided, but it is important to teach the men moderation. The allowance per man per diem should never be more than a quart, and men would find themselves healthier with a single pint per day. But it would seem probable that, especially in the hot stations and seasons, entire abstinence should be the rule, and that infusions of tea and coffee are the best beverages.*

The other point is, that in the tropics there is perhaps even a greater tendency to scurvy than at home; the use of fruits, then, is of great importance, and whenever practicable, the growth of fruit trees should be encouraged in the neighbourhood of stations. In some stations (Mooltan) lime juice has been issued with the greatest benefit when vegetables were scarce.†

Health of the Troops.

The chief statistics of the forces in India are contained in—

1. Numerous scattered papers in the various Indian medical periodicals for the last thirty years, referring chiefly to the health of one presidency or of regiments or forces occupying small districts.

2. Summaries of the whole, by Colonel Sykes (for twenty years ending 1847, "Statistical Journal," vol. x.), Sir Ranald Martin ("Influence of Tropical Climates," 2d edition), Mr Ewart ("Vital Statistics of European and Native Armies," 1859); Drs Waring and Norman Chevers ("Indian Annals," 1858–1862); and as far as officers and civilians are concerned, by Colonel Henderson ("Asiatic Researches," vol. xx.), and Mr Hugh Macpherson.

3. Official documents, the most important of which are contained in the Indian Sanitary Report; in the yearly Army Medical Department Reports since 1860; in the various Reports of the Sanitary Commissioners in the three Presidencies, and in the Municipal and other Official Reports sent in from towns or districts. At present the most valuable information is being collected and published in India of the health not only of the European and native armies, but of the civil population; and records of population and of births and deaths are now commencing to be systematically made. For the first time the Indian Government is gradually obtaining a view of the state of health of the numerous nations it controls.‡

India, taken as a whole, presents in many respects the same history as regards Europeans as our other tropical possessions. In former years there was a large mortality, attributed usually to the climate, instead of being put down to its proper causes, viz., a reckless mode of living amidst the most insanitary conditions. Gradually, as years have passed, the same gradual improvement has occurred in India as in the West Indies. Habits have improved, and the conditions of life have been slowly altered for the better. This change has been going on for years,§ and there has been an astonishing

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* The drinks which the private soldier often buys in the bazaars in India are of the worst description; arrack mixed with cayenne and other pungent substances, or fermenting toddy mixed with peppers and narcotics, or drugged beer, are common drinks. It would be easy to put a stop to this by legislative enactment.

† Dr C. A. Gordon—Memorandum on Rations, 1865, p. 11.

‡ The Reports from Bengal (Annual Reports of the Sanitary Commissioner with the Government of India) and those from Madras and Bombay are models of their kind, and must have a great effect on the health of the inhabitants of all India. The information given in these excellent Reports is so copious, that it is impossible to give any adequate account of it in this short chapter. I have been able only to note the most striking points.

§ See Dr Goodeve's paper in the Memorandum on Measures adopted for Sanitary Improvements in India up to the end of 1867—Bluebook (printed by order of the Secretary of State for India in Council, 1868). Also Dr Gordon's History of early Sanitary Improvements in India (*Med. Times and Gazette*, 1868-69).

progress since the mutiny. Much, no doubt, remains to be done, but the fall in mortality and in sickness has been so marked in all the Presidencies, as to lead us to hope that in a few more years the Indian service will, like the West Indian, be almost as healthy as the home service. It may seem rash to anticipate such a result, but an improvement as great has already taken place, for the mortality even now has fallen one half, compared with that of thirty years ago.

The following table shows this :—

Earlier Years.—Mortality of Europeans, per 1000 *of Strength.*

Years and Authorities.	Bengal Presidency.	Bombay Presidency.	Madras Presidency.
1828–47 (Sykes),*	73·8	50·7	38·46
1845–54 (Chevers), . . .	63·38	60·2	59·2
1838–56 (Queen's troops alone—Balfour), . . .	79·2	61·1	62·9
1806–56 (Company's troops alone — Indian Sanitary Commissioners), . . .	74·1	66	63·5

In 1812–16, in the Bengal Presidency, the deaths averaged 96·5 per 1000; in the Bombay Presidency in 1819–20 the deaths were 80 per 1000.

The above mean mortality includes every loss; in some years it was, of course, greater, in some less; but on the whole large every year, with a few exceptions, till the year 1856. After the mutiny, about the year 1860, the sanitary improvements and the greater care of the troops which had been gradually taking place received an immense impulse. The results are shown below.

Later Years.—Mortality of Europeans, per 1000 *of Strength.*

Years and Authorities.	Bengal Presidency.		Bombay Presidency.	Madras Presidency.
	Total Mortality.	From Disease alone.†	Total Mortality.	Total Mortality.
1860–65 (Balfour),	31·26	29·34	25·21	21·75
1866 (Balfour), . .	23·19	20·03	15·06	24·08
1867 (Balfour), . .	33·91	30·49	19·21	21·40
1866 (Third Bengal and Madras Sanitary Reports),	20·11‡	...	...	21·7
1867 (Fourth Bengal Sanitary Report), . . .	30·95§	...	...	...

* Ewart's numbers, taken from a longer series of years, are almost the same.

† Cases of Insolation are not included in this column.

‡ The discrepancies between this and other Indian returns and Dr Balfour's figures, which are calculated in England, arises from the fact that in the latter case the invalids dying at Netley are included; Dr Balfour's numbers are therefore always higher, as the others include only those dying in India.

§ The increase in mortality was owing to the great outbreak of cholera in 1867, which destroyed 13·84 per 1000 of strength.

The mortality increases with age in the following ratio for all India (average of 4 years):—

Under 20 years,	7·11	per 1000 of strength.
From 20 to 24 „	16·19	„
„ 25 „ 29 „	25·64	„
„ 30 „ 34 „	32·03	„
„ 35 „ 39 „	42·78	„
„ 40 and upwards,	56·34	„

Causes of Death.

The following table is compiled from Dr Balfour's reports, and represents the deaths occurring both in India and on the voyage, and at Netley, but the results are not very different from those occurring in India alone:—

Per 1000 *of Strength.*

Diseases.	Bengal.		Bombay.		Madras.	
	1860–65 (=Six Years).	1866.	1860–65 (=Six Years).	1866.	1860–65 (=Six Years.)	1866.
Cholera,	8·82	1·30	6·08	1·66	3·18	2·47
Dysentery and diarrhœa,	3·98	2·34	3·36	1·16	2·71	4·66
Paroxysmal fevers,	2·23	1·92	5·9	·75	·73	·97
Continued fevers (nature uncertain; in part enteric, in part malarious),	1·51	1·27	1·11	1·32	1·29	1·14
Eruptive fevers,	·17	·36	·25	...	·06	·26
Tubercular diseases (phthisis, scrofula, hæmoptysis),	2·49	2·71	1·88	3·07	2	2·72
Diseases of the nervous system,	2·04	1·27	1·5	·99	1·47	1·23
Diseases of the circulatory system,	·86	1·61	·82	·66	1·13	2·11
Diseases of the respiratory system,	1·12	1·24	·9	·66	·66	·44
Diseases of the digestive system,	3·82	3·47	3·43	2·07	3·87	4·04
Diseases of the urinary system,	·16	·31	·06	·25	·19	·09

It will be seen from this table that the Bengal Presidency shows a marked predominence of cholera and fatal paroxysmal fevers, and this has always been the case. The so-termed "continued fevers" are nearly the same in amount in all the presidencies.

The heading of "diseases of the digestive system" includes the fatal class of hepatitis, which causes $\frac{4}{5}$ths or more of the deaths of this heading. Bengal and Madras are almost equal (losing 3·8 men annually out of every 1000), while Bombay is somewhat lower. But still the difference is not great between the three presidencies.

The following table of deaths occurring in India will put more clearly the

relations between the presidencies of Bengal and Madras. They are returns for one year only, but represent fairly the usual course of events, except that the average deaths from cholera in Bengal were only 7·7 in the seven previous years:—

Bengal, 1867.*		Madras, 1866.*	
Total Diseases in order of frequency.	Deaths per 1000 of strength.	Total Diseases in order of frequency.	Deaths per 1000 of strength.
Cholera, ...	13·84	Dysentery, ...	2·7
Fevers, ...	2·63	Cholera, ...	2·5
Hepatitis, ...	2·57	Phthisis pulmonalis, .	1·7
Apoplexy, ...	2·40	Hepatitis, acute, 1·7, }	2·9
Dysentery, ...	1·97	,, chronic, 1·2, }	
Phthisis, ...	1·36	Dysentery, chronic, .	1·1
Heart disease, . . .	1·16	Heart disease, . . .	1·1
Respiratory diseases, .	·84	Insolation, ...	·8
Delirium tremens, . .	·4	Fever, continued, . .	·8
Diarrhœa, ...	·4	,, intermittent, .	·7
Wounds and accidents,	·29	Wounds and accidents,	·8
Atrophy and anæmia, .	·17	Diarrhœa, ...	·6
Dropsy, ...	·14	Respiratory diseases, .	·5
Smallpox, ...	·12	Delirium tremens, . .	·3
Scurvy, ...	·03	All other, ...	4
All other, ...	2·63		

There would seem little doubt that of late years the reduction in the mortality has been chiefly in the class of fevers, dysentery, and hepatitis, in the latter case resulting (as Ewart has indicated) chiefly from the greater temperance in eating and drinking.

There are two headings in the table which seem to demand from Indian officers a more thorough investigation. What are those fatal diseases which appear as paroxysmal and continued fevers? The only fatal malarious fevers are the intense remittents, from which troops only suffer in special localities. As a rule, however deeply malarious fever invades the constitution, and however obstinately it clings to it, it is not, in the first instance, a fatal disease; witness the slight mortality in the most malarious country of all our foreign possessions, Demerara. What, then, are the forms of those paroxysmal fevers, which every year kill two or three men in every 1000? If they are malignant remittent, there must be great and unnecessary exposure at some points.

So also with the return of "continued fever;" is this also a severe malarious fever, or typhoid or relapsing fever, both of which occur in India?

Surely something could be done to investigate and remove the causes of these fevers. They must be preventible. Dysentery is also decidedly falling both in admissions and mortality; the decrease in the latter point depending partly on improved treatment. I refer to the chapter on the Prevention of Disease for the rules to be followed in the case of dysentery and (as far as we can venture to state them) of hepatitis.

The amount of phthisis in India is a highly interesting question; in the

* This table is taken from the Sanitary Reports of the Presidencies.

following table I have calculated the admissions, deaths, and invaliding from this cause :—

Phthisis and Hæmoptysis per 1000 *of Strength, years* 1863-66 (= 4 *years*).

	Bengal.	Bombay.	Madras.	All India.
Admissions, . .	7·5	7·756	11·526	...
Deaths (in India or at Netley), . .	1·707	1·526	1·458	1·563
Invalided, . .	2·729	3·280	3·656	3·222
Total deaths and invalided, . .	4·436	4·806	5·114	4·785

In two presidencies the mortality is almost precisely the same. How regularly the causes of phthisis must be acting, is seen in the fact that in four years 74 men died from phthisis in the Bombay Presidency, and 73 in the Madras Presidency, the mean number of troops being in each case almost precisely the same (12,119 and 12,512). In the Bengal Presidency, if the same ratio had occurred, there would have been 231 deaths from phthisis; there were actually 264, but then the invaliding was less from Bengal, so that the slight difference is compensated. More men died, and fewer were sent away.

The table seems to me to show clearly that the immense range and variation of climates in which the troops serve in India, produces no effect whatever on the production of phthisis; and this inference is again strengthened by the fact that the mortality in Bengal from phthisis is almost precisely the same as in Canada (1·707 and 1·71 per 1000).

If the Indian mortality and invaliding are compared with the table already given of phthisis in the home army (p. 535), it will be seen that there is decidedly less phthisis in India. The mortality is less, and the invaliding is far below. There can be no doubt, then, that the causes of phthisis are less active in India than at home, and if these causes are not climatic, must the difference not be found in the larger breathing space and greater lateral separation men have in India?

It would be interesting to have some certain statistics of the amount of phthisis in former years, when men were more crowded; Ewart* gives the deaths in the Bengal Presidency, from 1812 to 1831, as 2·6 per 1000 of strength, and from 1832 to 1851–52, as 1·8 per 1000. In the Bombay Presidency, from 1803 to 1827, they were 1·6, and from 1828 to 1852, 1·4 per 1000. Ewart thinks this indicates a large decrease, but doubts whether this may not be owing to more accurate diagnosis. The table just given shows, however, that in Bombay at any rate the deaths in the years 1863–66 were as great as in 1828–52. In the early period, however, there may have been less invaliding. In the absence of reliable statistics, the question of the relative amount of phthisis now and formerly seems to me impossible to be answered.

With respect to the cure and prevention of phthisis, it seems a great pity to send phthisical invalids to England, where they die at Netley, or are cast out to die miserably among the civil population, when in the Himalayas there are elevated localities which must be particularly adapted for the successful treatment of consumption. When means of communication are improved, it

* Vital Statistics of the Armies in India, 1859, p. 164.

is possible that we may see phthisical invalids going from Europe to the high peaks of the Himalayas, and why should not the European soldier, who is actually in India, benefit by these mountain ranges? A phthisical sanitarium, at an altitude of 10,000 feet, would be likely to cure the disease in many cases, if it were diagnosed early, and then if the men were afterwards kept on the lower hill stations, they would probably become perfectly strong. To send these men home to England is condemning them to almost certain death. Formerly the distances in India would have been fatal to such a plan, but now, by proper arrangements, even weakly men could be brought from all parts of India. Dr Hermann Weber, who has paid great attention to the effect of altitude on phthisis, holds very decided views as to the beneficial effect of such an arrangement, and has already urged this point on the attention of the authorities.

The other diseases of the lungs are not unknown in India. Pneumonia gives a mortality in Bengal of about ·5 per 1000 of strength, or a little less than at home (=·571); while in the other two presidencies it is not half this amount. Acute bronchitis also causes in all the presidencies a mortality almost precisely the same as at home (·27 and ·285 per 1000).

*Mortality of Native Troops.**

Colonel Sykes gives the mortality for 1825–44 as 18 per 1000 of strength for all India; and for Bengal, 17·9; Bombay, 12·9; Madras, 20·95.

In Madras, from 1842 to 1858, the average was 18 per 1000 (Macpherson), of which 6 per 1000 each year were deaths from cholera.

Ewart gives the following numbers (p. 36), per 1000 of strength—Bengal (1826–1852), 13·9; Bombay (1803–1854), 15·8; Madras (1827–1852), 17·5.

Taking successive quinquennial periods, there has been a slight progressive decrease in mortality, but this is less marked than in Europeans.

The excess of mortality is chiefly due to cholera, dysentery, and fever.

In Bengal, in the years 1861–67, the annual mortality per 1000 of men present with the regiments was 14·57. In Madras the average mortality in six years, 1860–66, was 12·6.

In the year 1867 the chief causes of deaths among the Bengal and Madras native troops were—

	Per 1000 of Strength.	
	Bengal. 1867.	Madras. 1866.
Cholera,	3·17	3·4
Fevers,	3·04	2·
Dysentery,	1·05	·8
Respiratory diseases,	·97	·8
Phthisis, pulmonary,	·61	·5
Atrophy and anæmia,	·38	·8
Spleen disease,	·26	·07
Heart disease,	·26	·4
Hepatitis,	·23	·1
Apoplexy,	·23	

Invaliding of Europeans.

	Invalids sent Home, per 1000 of Strength.		
	Bengal.	Bombay.	Madras.
Years 1861–66, six years,	37·44	33·86	44·35

* Third and Fourth Bengal Reports, pp. 118 and 187.

Of these rather more than half are eventually discharged the service. It appears that the Madras Presidency, in which the mortality is least, invalids the largest number.

The causes of invaliding are chiefly tubercular, hepatic, and rheumatic and ophthalmic affections. Venereal diseases also cause a considerable loss.

Loss of Service—European Troops.

	Per 1000 of Strength, 1860-65.		
	Bengal.	Bombay.	Madras.
Admissions, ...	1785	1654	1381
Mean daily sick, . . .	67·26	64·07	62·47
Days in hospital to each sick man,	13·76	16·51	14·14

As compared with home service, a larger number of admissions, a greater daily number of sick, and a shorter duration of cases, and a larger mortality, indicate not only more sickness, but the presence of very rapid mortal diseases, which shorten the mean duration of all cases.

The chief causes of admission are "paroxysmal and continued fevers," venereal disease, dysentery, rheumatism, integumentary diseases, and digestive affections (not hepatitis). Hepatitis and cholera cause few admissions, but a large mortality.

With regard to the prevention of those several diseases enough has been said in the chapter on the PREVENTION OF DISEASE. There is no doubt that much may be done, and probably the sickness and mortality will be reduced, if hill stations are used, to the same ratio as in the West Indies.

It is most satisfactory to find that the sickness and mortality are both rapidly falling, owing to the energetic means now being adopted by the Government, and to the increased sanitary powers and improved curative means of the medical officers.

The prevalence of venereal disease demands as much attention in India as in England, but the preventive measures will be much easier. Police regulations and proper surveillance are now being enforced, and Lock hospitals are established in many places. At present twelve men per company are allowed to marry, and it has been supposed by military officers that 25 per cent. could be so allowed. This is much to be desired; but if it be done, the Government must face certain results; proper quarters must be provided, and places for disposal of the women in times of service. It is also very desirable for married men, not to move regiments too frequently; and if the plan of giving a regiment two years' service in the hills and one on the plains be adopted, it will put the married people to great expense. Probably it will be found that a longer hill service can be given without injury.

Another result can be foreseen: if the term of Indian service be shortened to ten years, it will be a great inconvenience to the married men to return home, and it is quite clear that a very great number of them will constantly volunteer to remain. This is indeed, perhaps, desirable, as keeping steady married men who know the sort of life in India; but it is not the result contemplated by the plan of frequent reliefs.

Arrival in India.

The Queen's Regulations order that the time of arrival in India be between the end of October and March. But the latter time is rather late. It appears to be an almost invariable rule that soldiers on disembarkation in India show a large sick list during the first three or four months. They frequently land in robust health; they have been well fed

during the voyage, and have had little exercise, and are often, indeed, too plethoric. The excitement of landing, the new scenes, the welcome, and too great hospitality of comrades, the exercise under unusual conditions of heat, the altered diet, all act unfavourably, and their own excesses add to the evil. As they usually land at the presidencies, they are at once exposed to the influences of these towns, and may suffer very soon from cholera, or malarious fever. In addition to what has been advised elsewhere, it is of great importance to fully carry out a measure already commenced by the Government,* viz., not to keep the men longer than absolutely necessary at the presidencies (not for a day if possible), but to move them inland. If it were made a rule to send every fresh corps at once to the hills for two years after landing, it would probably be the means of saving many lives. One difficulty is that the best hill stations are a long way from the sea-ports, but the railways have somewhat lessened that objection.

The advantages of the hills are, not merely the avoidance of malaria, and the excessive high temperature of sea-level or inland plains, but the fact that exercise can be taken freely in a temperature not very different from England. Would it not be possible to use the fine station of Newera Ellia or Horton in Ceylon as a station of transit for Bengal? Madras can use the table-land of the Deccan or the Neilgherry Hills, and Bombay has its stations on the Ghauts.

One more point will require attention in India, and that is the health of the women and children. There has always been a very large mortality of children, and at certain stations of women. For them the transference to the hills is the most important preventive measure, and probably nothing else will do more than slightly lessen the great yearly loss of children.

SECTION IX.

CHINA.

Hong-Kong.

Although the English have occupied Canton, Tientsin in the north, and several other places, yet, as their occupation has been only temporary, it seems unnecessary to describe any other station than Hong-Kong.

Garrison of Hong-Kong about 1000 to 1500, but differing considerably according to the state of affairs in China.

The island is 27 miles in circumference, 10 long, and 8 broad at its widest part.

Geology.—The hills are for the most part of granite and syenite, more or less weathered. In some parts it is disintegrated to a great extent, and clayey beds (laterite) are formed, in which granite boulders may be embedded. Victoria, the chief town, stands on this disintegrated granite. As in all other cases, this weathered and clayey granite is said to be very absorbent of water, and, especially in the wet season, is considered very unhealthy.

Climate.—Mean annual temperature, 73° Fahr. ; hottest month (July), 86°·25 ; coldest month (January), 52°·75; amplitude of the yearly fluctuations, 33°·5.

The humidity is considerable, about 10 grains in a cubic foot of air in July, and four in January.

* Especially by the Bengal Government since 1856 ; the men are sent on arrival to Dum-Dum or Chinsurah, and are then sent to the north-west as soon as conveyance can be found.

The N.E. monsoon blows from November to April; it is cold, dry, and is usually considered healthy and bracing; but if persons who have suffered from malaria are much exposed to it, it reinduces the paroxysm. The S.W. monsoon blows from May to October; it is hot and damp, and is considered enervating and relaxing. The difference in the thermometer between the two monsoons has been said to be as much as 46°, but this seems excessive.

The rainfall is about 90 inches with the S.W. monsoon.

In addition to Victoria, there are two or three other stations which have been occupied as sanitaria, viz., Stanley, seated on a peninsula on the south end of the island, and about 100 feet above the sea; and Sarivan, 5 miles east of Victoria. Neither station seems to have answered; the barracks are very bad at Stanley, and are exposed too much to the N.E. monsoon, which, at certain times, is cold and wintry; during the S.W. monsoon it is healthy. Sarivan has always been unhealthy, probably from the neighbourhood of rice fields. Since the close of the last war a portion of the mainland, Cowloon, opposite Victoria, has been ceded, and has been occupied by troops. It is said not to be, however, even so healthy as Hong-Kong,* but there are differences of opinion on this point.

Hong-Kong has never, it is said, been considered healthy by the Chinese. The chief causes of unhealthiness appear to be the moist laterite and weathered granite, and the numerous rice fields. Indeed, to the latter cause is ascribed by some (Smart)† the great unhealthiness, especially when the rice fields are drying in October, November, and December.

Local causes of unhealthiness existed till very lately in Victoria. In building the barracks the felspar clay was too much cut into, and, in addition, the access of air was impeded by the proximity of the hills. The S.W. monsoon was entirely shut out. Till lately sewerage was very defective.

Owing probably to these climatic and local causes, for many years after its occupation in 1842, Hong-Kong was excessively unhealthy. Malarious fevers were extremely common, and not only so, but it is now known that typhoid fever has always prevailed there (Becher and Smart). Dysentery has been extremely severe, and has assumed the peculiar form of lientery. This was noticed in the first China war, and appears, more or less, to have continued since. In addition to these diseases, phthisis appears to have been frequent.

There have been of late years such frequent wars in China, that the exact amount of sickness and mortality, due to the climate of Hong-Kong, cannot be well determined. But it is becoming much healthier than in former years, owing to the gradual improvement in sanitary matters which goes on from year to year. In 1865 there was, however, much sickness, owing apparently to overcrowding, and to bad accommodation.

In the Statistical Reports, the troops serving in Hong-Kong, Cowloon, Canton, and Shanghai, are classed together, so that the influence of Hong-Kong *per se* cannot be known.

In the years 1859–66, which include years of war, the admissions in South China averaged 2131, and the deaths 56·25, or, exclusive of violent deaths, 52·63 per 1000 of strength, and there was in addition a large invaliding. Paroxysmal fevers gave 609 admissions and 7·77 deaths; continued fevers, 25·25 admissions and 4·17 deaths; and dysentery and diarrhœa, 249 admissions and 16·3 deaths per 1000. It is therefore evident that there must be

* See Report of Surgeon Snell, "Army Medical Report," vol. v. p. 360, for the causes of the unhealthiness of Cowloon.

† Transactions of the Epid. Soc., vol. i. p. 191. This paper should be consulted for an excellent account of Hong-Kong, and of the diseases among sailors especially.

a vast amount of preventible sickness still to be got rid of, and the immense mortality of dysentery contrasts strongly with India. It is probable in part scorbutic dysentery, and will be lessened by proper diet. Enthetic diseases are now lessened by police regulations.

SECTION X.

AUSTRALIA AND NEW ZEALAND.

Australia.—It seems unnecessary to describe the climate of Australia. The number of troops stationed in Australia (New South Wales, Victoria, Adelaide, and Western Australia) and Tasmania is now small, not more than 6000. During the years 1859–66 there were in Australia and Tasmania 707 admissions and 15·05 deaths, or, without violent deaths, about 14·5 deaths per 1000. In 1867 the deaths were 7·51 per 1000.

These countries at present are known to be very healthy; this arises in part from the absence or great infrequency of malaria; the exanthemata also are less common and virulent, and phthisis among the civilians is supposed to be infrequent, though it is certainly not so among the troops, the average deaths from tubercular disease being (mean of 8 years, 1859–66) no less than 5·3 per 1000 of strength, or far more than at home or in any other station of the army. There was also invaliding. This does not seem to bear out the general impression of the absence of phthisis in Australia, or, what is more probable, climate has little to do with it, and the troops are simply under some conditions from which civilians are free.

New Zealand.—The frequent wars in New Zealand render it rather difficult to judge of the effect of the colony on the health of the troops. It has always been considered healthy. In the years 1859–65 there were (men killed in action and other violent deaths being deducted) only 606 admissions and 8·26 deaths per 1000 of strength. In 1866 there were 448 admissions and 8·76 deaths. The deaths from tubercular diseases in that year were only ·36 per 1000 of strength, showing that New Zealand contrasts remarkably with Australia in this respect. The open-air life the troops have led has probably brought about this result. In 1867 the deaths in New Zealand were only 4·55 per 1000 of strength. In 1862, one regiment (65th) had only 4·78 deaths per 1000 from all causes, an almost unexampled degree of health. In 1863 there were 22·49 deaths per 1000, but 12·46 were in battle, and 2·77 were also other violent deaths, so that the total from disease was only 7·26 per 1000; of these tubercular diseases give 1·73 per 1000. In spite of the hardships of eight months' war, the admissions were only 568·7 per 1000; the ratio constantly sick was only 30·28 per 1000, an extremely small amount for a period of war.

Tubercular diseases cause a mortality of 2 per 1000, including the deaths of invalids on the passage home.

Among the diseases causing admissions, ophthalmia, bronchitis acuta, phlegmon and abscess, diarrhœa, acute and chronic rheumatism, and "continued fever," give the greatest number of admissions. The latter is probably febricula, as in 1862, among 114 cases, there was not a single death.

CHAPTER IV.

SERVICE ON BOARD SHIP.

Service on board ship must be divided into three sections, corresponding to three different kinds of service.

1. Transport ships, for the conveyance of healthy soldiers, their wives and children, from place to place, or for conveying small parties of troops in charge of convicts.

2. Transports for conveyance of sick from an army in the field to an hospital in rear, or from a foreign station to a sanitarium, or home. Although the term is a little odd, it is convenient to call these ships Sick Transports.

3. Hospital ships, intended for the reception and treatment of the sick.

SECTION I.

TRANSPORTS FOR HEALTHY TROOPS.

At present Government employs steam-vessels of its own which convey troops, and the use of hired vessels is being gradually given up. The Government vessels are fine, roomy steamers, and are well fitted. Before troops are permitted to embark, they are carefully inspected by the principal medical officer and the medical officer in charge, and any man with any disease which may prove injurious during the voyage is kept back. Every man is therefore supposed to embark in perfect health ("Queen's Regulations."—*Embarkation of Troops.*)

Regulation for hired Transports.

The "Medical Regulations" (Part iv. section v.) order the principal medical officer at the port of embarkation to inspect the ship, and to ascertain the tonnage per man;* the height between decks; the cubic space, superficial area, and means of ventilation; the cleanliness of the ship, bilge, and water-closets; that there is sufficient chloride of zinc, and a fumigating apparatus on board; that stoves are provided; that cots, bedding, utensils, and cooking arrangements are sufficient; and that the stoves, water, and medical comforts are good and sufficient.

In the Queen's Regulations (section xxiii.) the "Duties on Board Ship" are very explicitly stated. This chapter should be very carefully read over, and constantly referred to. As it would be impossible to put in these long directions here, I shall assume that every officer thoroughly knows these regulations. A scheme of diet is ordered (Regulations for Her Majesty's Transport Service), additional clothing is given, viz., a canvas tunic or blouse.

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* The Queen's Regulations order 270 tons (new measurement) for 100 men.

Inspection of Transports at the Port of Embarkation.—The Assistant-Quartermaster-General and the Principal Medical Officer make an inspection of all hired transports, as already stated. It is of importance that the medical officer who is to be in charge of the troops should be present, and this should be ordered whenever it can be done; occasionally, however, the medical officer may be with his regiment, and does not see the ship till the men are actually embarking.

The inspection of the ship should be conducted like that of a barrack. A ship is, in fact, a floating barrack.

1. *Amount of Space.*—The measurements on board ship are not always easy, but by attention to the rules at page 149, the various irregular spaces will be determined. No special amount of superficial or cubic space is ordered; this is determined by the tonnage (1 man to 2·7 tons), but this plan is not a good one. The loftier the space between decks and the greater the cubic space the better.

2. *Ventilation.*—In the Government transports there are windsails and ventilating tubes, in addition to port-holes and hatches. Most hired transports have no means of ventilation except opposite ports (which are often obliged to be closed), hatches, and windsails. Windsails are large tubes made of sailcloth closed above, but having on one side a large open mouth or slit. The windsail is tied to a yard or rope, the upper part being some four or six feet above the deck, and the lower open end passing down between decks. The open mouth is turned towards the wind, which then blows down the tube. A great deal of air enters in this way, but is often badly distributed. The best plan is to close the lower end and to have several lateral openings at different heights, and in all directions; it would be well, also, to have the upper of these lateral openings rather smaller than the lower, as the wind will blow more forcibly through the upper holes. Another very good plan is to make the windsail long enough to be carried some way between decks, and not merely, as usual, open at the bottom of the hatches; openings can then be made at intervals in it. Any curves in a windsail should be large, so as to avoid choking, or the calibre should be held open with hoops at this point. The air should be let in near the lower deck, and as far as possible from the outlets.

If a ship has open stern ports, this is a great advantage, but generally there are cabins, or cargo, which block the stern ports from the between-deck.

Hatches are always very uncertain means of ventilation; they are also obliged to be closed during stormy weather—in fact, at the time when most of the men are below, and when the ventilation is worst. In bad weather the following arrangement may be adopted:—Suspend a spar a few feet above the main hatch, and let a tarpaulin fold over it like a tent; this can often be kept open at one side, or at both for a time, and closed at once if necessary. In very severe weather, of course, this will not answer. In the smaller hatches a frame of wood or rope can easily be arranged, which the tarpaulin can cover.

But with all care the ventilation between decks is never good with hatches and windsails merely, when the ports are closed. Let any one visit a hired troop-ship about three hours after the men are in bed, or even a man-of-war: the air is excessively fœtid, very moist, extremely hot, the temperature above the men's heads being sometimes 6° or 8° higher than below the hammocks; and those who go in from the pure air can hardly bear the odour.* The move-

* The effect of this bad ventilation on the sailors of the Royal and Merchant Services is very serious. See especially Gavin Milroy's paper before referred to.

ment of air is extremely small when the ports are closed. At the hatches the hot air gets suddenly cooled, and its ascent is checked. Usually, however, a double current is established in the hatchway, but this is not nearly sufficient.

Other plans must be adopted. Dr Edmond's plan of ventilation is now used in all the emigrant ships, and is being adopted in the Royal Navy. In the case of a steamer, the space round the funnel is encased, and serves as an outlet, or the funnel itself is used; the spaces between the timbers and between-decks are all brought into connection, and the air is led from them by shafts to the central shaft. By this plan, the bilge and hold, as well as the between-decks, are purified. If the vessel be not a steamer, there is a stern or central shaft, up which there is, I believe, always a good current.

If the hired transport is not thus ventilated, tubes must be arranged at different points leading to the between-decks. Sometimes two tubes (one at each side) have been placed at the fore and two at the after part of the ship; according to the wind, two are outlets and two inlets; there may be a strong current, but the respired air in this way is obliged to pass over a number of persons. It would seem better to fix several tubes along the sides or centre, to cover them with cowls turning to or from the wind, so as thus to have a certain number of inlets and outlets. If it can be done, a narrow central opening along part of the deck, with a low plank at either side to keep out water, and covered by a louvre, is a very good plan, and is a very efficient outlet.

The exact size and number of the tubes has not yet been experimentally determined; probably, as there is a good deal of wind, these need not be so large as in houses on shore, but it is always best to have plenty of them. If necessary, some can be closed. Perhaps a round tube of eight inches diameter would do for ten persons, giving five inches to each for inlet and outlet. Of course, hatches, windsails, ports, and tubes should all be in action at the same time.

Arnott's pump is said to be a most useful plan; the ends of the pump, where the fresh air is to flow in, are connected by canvas tubes with the open air, and the discharge outlets are left open, or, if desired, can be connected with a canvas or wooden tube, so that the air may be sent to some distance. But care should be taken not to increase friction. Arnott's pump may be made double, with vertical pistons working on the plank forming the junction of the double pump; if properly made, a child can work the suspending double piston. Other machines of a like kind have been used.

Sometimes propelling and extracting fans or screws are connected with the steam-engine, and air is drawn out or blown in.

Cabins should be ventilated by tubes passing up and opening on deck; they should be recurved, so as to prevent rain or water splashing in. If the cabin lamp is fixed below the opening, a strong current is obtained.

3. *Water Supply.*—The tanks should be carefully examined, the quantity determined, and the quality examined. (See chapter on WATER.) If there be a distilling apparatus, this should be examined. In a sailing vessel, small stills should be fixed to the top of the ship's coppers.

Condy's fluid should always be taken to sea, as well as charcoal and alum.

4. *The food* is inspected as follows:—A cask of salt-beef and pork is opened, and the pieces looked at. One or two tins of preserved meat are opened; samples of flour, porter, &c., medical comforts, such as beef-tea, arrowroot, &c., are examined. The rules have been already given in the chapter on FOOD. It is important to take time in this examination; not to slur it over, and especially to test the lemon-juice carefully. If there are many children

on board, large stores of arrowroot, preserved milk, and children's farinaceous food, should be laid in.* The cooking apparatus should be next examined, and it should be seen that there are proper means for removing all refuse, which is often allowed to accumulate.

5. *The state of the hold*, spaces between bunkers, bilge, and cargo, if any, should be next seen to; chloride of zinc should be taken to mix with the bilge water.

6. *Arrangements for Washing.*—These are generally very defective on board hired transports; on board Government transports a lavatory might easily be fitted up. A good forcing pump and hose should always be on board, for getting up salt water. At present, in most merchant transports, the arrangements for these things are most primitive and incomplete. The bucket is still perhaps the only way of getting up water, both from the water-tanks or sea.

7. *The closets* are usually fixed on either side, in front of the forehatchways or in the head. If women are on board, one should be kept for them and for the children. The opening should be just below the water-line. It has been suggested to have a double set of latrines, and only to use those on the leeward side (Kirwan). This seems a good suggestion. Considering that everything passes into the sea, it might be supposed that nothing would be easier than to keep the closets and head clean, but this is not the case, owing to the usual deficiency of water; it is usually considered sufficient to haul up the water in buckets and to pour it down; instead of this, force pumps should be used; they can be so made as to be worked most easily, and with a proper distribution of the water all round the rim of the seat, the places can be kept quite clean. The closets and shafts are often made of wood, but wood gets excessively foul; they must be of zinc. Sometimes the soil is allowed to fall against the side of the ship, which soon gets impregnated, and if a porthole is near foul air drifts in. A metal plate should lie against the side, and be scraped every now and then, or if this cannot be done, a piece of wood, which should be cleaned from time to time.

8. *The medicine chest* is next examined (see Medical Regulations).

Duties during the Voyage.

The health and comfort of the troops during the voyage depend entirely on the commanding officer and the medical officer.

The Queen's Regulations are so full and clear, that the work must be done in a particular way. These regulations must be followed to the letter. But, of course, there should be a certain system and order in carrying out both the word and spirit of these regulations. The system usually adopted is something of this kind. Before embarkation the men are told off in messes of six, and the various articles of the sea-kit are allotted. Whenever practicable, troops should be on board 36 hours before sailing; their berths are allotted and packs hung up; arms put in the racks; sea-kit arranged, &c. Troops are then told off, three watches each, commanded by a subaltern, who is in charge of the deck; a guard of a certain strength is ordered, and sentries are placed over the hatchways, cook-houses, forecastle, &c. A certain number of men are told off as cooks, and others (one to each mess) as swabbers. A

* In several cases in which there occurred a large mortality of children, during voyages, &c. in which the symptoms are recorded, it will be found that gastro-intestinal affections and tabes were the causes of the sickness and mortality. The mesenteric glands are evidently injured by the passage through the glands of half-digested and unwholesome food. The kind of food and cooking on ship board generally account for the sickness of children, if the exanthemata are not present.

portion of the between-decks is fixed as an hospital, if this has not been done; a portion is assigned to the women and children, and screened off. At reveille, troops and women and children turn out, fold hammocks, and take them on deck, if the weather permit; the hammocks are stowed away by the swabbers till evening. Before, however, the bedding is brought up, the upper deck is washed by the watch. The men remain on deck, except the swabbers, who clean the between-decks, thoroughly ventilate, &c.

Directly they are on deck, the washing of the men begins; two large tubs are fixed on the forecastle; in many ships the men get buckets of water thrown over them, and if one or two good force pumps and hose are on board, every man should be *douched*. The men wash, comb, and brush their heads every morning. After washing, the men parade for inspection by a serjeant, who sees that the hands, arms, face, and feet are clean. The men's breakfasts are then served; after breakfast is cleared away, there are parade and drills, or, according to circumstances, fatigue duties. Twice a week there are washing parades for clothes; the washing should be done early, and the clothes hung up to dry. A soldier is expected to shave and to have a clean shirt twice a week at least.

If the troops are very numerous, it may be necessary to divide them into two or more sets for washing both persons and clothes, and to have different days. If there are women and children on board, one day is set apart for their thorough bathing, a screen being put up on deck. For washing, a certain quantity of marine soap is issued, but it is said to be insufficient. Dr Kirwan states that 8 ℔ per head for a voyage for four months is the proper quantity. During the day the troops are encouraged to take exercise and amusements. In harbour, and at other convenient times, the men bathe when there is no danger of sharks, a sail being let down for those who cannot swim. The men are advised not to sleep on deck.

There are one or two points which must be noticed. The turning out of the women and children is essential, but it should not be done till after the men have washed; about 9 o'clock is a good time. Especially during the first few days after starting, when the women are sea-sick, the medical officer is often implored to speak to the officer in command to permit them to remain below. But it is always better to get them up, even for their own good, and this should be explained to them. Without necessity, therefore, from decided illness, the medical officer should refuse the request.

The swabbing between decks is done by scraping, rubbing, and sweeping; not by washing, unless the weather is dry, and then only once a week. This is a very important rule; in fact, it would be well to avoid washing altogether, except in the very heat of the tropics. If there are berths, the lower boards should be removed now and then, so that every place may be cleaned.

The men are divided into three watches. One watch remain on deck at night. They are relieved every four hours. Officers are directed (Queen's Regulations, 1266) to use their utmost endeavours to prevent the men sleeping on deck in warm weather in the tropics, unless under awnings. When the weather permits, however, great good results from sleeping on deck. I paid particular attention to this point in India, and never found any man injured; there may be heavy dew, but a blanket keeps this off completely, and it does no harm. The pure sea air is infinitely better than the hot foul atmosphere between decks. I have made many inquiries from friends who have had far more experience lately of troops at sea than I have, and I have found they all approved of the men sleeping on deck when the weather permits.

The issue of lemon-juice is commenced ten days after the men have been at sea. A serjeant sees that each man drinks his share.

Duties of the Medical-Officer.—As on shore, he is charged to look after every point connected with the health of the men, and to mention such points as are necessary to the commanding officer. On board ship, as everywhere, the medical officer is under the orders of the commanding officer, but sensible suggestions are always welcome.

On first going on board, the medical officer should see that the hospital or "sick-bay" is properly arranged. The best place for the sick-bay is the best ventilated part, where there is not too much passage. If near the hatchways, there is no quiet. Ventilating tubes, &c., should be put in. A closet must always be provided, discharging into the sea, as well as patent close-stools.

Then the kit of medical comforts, medicines, and instruments should be gone over, and everything placed in order.

The daily duties are these :—Attendance at the sick-bay, reception of sick, preparation of morning state for the commanding officer.

Attendance at morning parade (Queen's Regulations, 1270), to observe any appearance of disease.

Also, for the first three weeks, health inspections should be held for the detection of venereal. It is best to hold two the first week; one three days after starting, so as to catch the disease at its very commencement.

For the first fortnight every child should be seen daily, to detect the first sign of scarlet fever, measles, or hooping-cough.

After the parades, the between-decks should be visited. By that time they will have been swabbed out. They should be carefully inspected and occasionally fumigated with nitrous acid and chlorine.*

In the sick-bay, if there are many patients, chlorine should be continually disengaged by means of the chlorine water. The bedding should be occasionally inspected, especially that of the women and children.

The rations should be looked at from time to time; they are always inspected by the orderly officer, and the medical officer is sure to be referred to if there is any complaint.

Inspect the latrines and the cook-houses regularly twice daily—morning and evening.

Take care that the bilge-water is pumped out whenever practicable; every day should be the rule.

If any specific disease appears on board, the most active measures must be taken to fumigate, isolate, &c. (see chapter on the PREVENTION OF DISEASES).

If diarrhœa appear, look to the water first, then to the latrines, then to the bilge, then to food, as the possible causes. Take special care to cleanse the latrines, as the disease may be communicable.

With regard especially to salt meat, see page 197 for the cooking of salt meat, and for the possibility of converting it into fresh meat by dialysis. Almost any skin or membrane will do as a dialyser.

In the cooking of the preserved vegetables, remember the use of potassium permanganate, if there be any smell; or if there is none of the permanganate, chloride of lime.

The administration of the lemon-juice should be carefully looked after. Every man should be seen to drink his allowance.

Duties on Disembarkation.

Usually the men are landed in excellent health, but almost always there is

* The Queen's Regulations (1262) order for chlorine—common salt four ounces, one ounce oxide manganese, sulphuric acid one fluid ounce (which is nearly two ounces by weight), water two fluid ounces; the vessel is to be placed in a pipkin of hot sand.

a large amount of sickness the first month after landing. This arises from personal irregularities, and the medical officer, before arriving at the port, should spend some time in talking to the men, and pointing out the inevitable consequences of misconduct and foolish irregularity. Intemperance especially is the grand cause of disease. The men on landing are placed in a position of temptation on account of the ill-judged hospitality and welcome of their comrades at the station, who think it necessary to show their pleasure at meeting by doing their best to make their friends ill. If a medical officer has been attentive during a long voyage, he will be sure to have acquired much influence with the men by the time they arrive at their journey's end. He should use this power for their good.

SECTION II.

TRANSPORTS FOR SICK TROOPS.

No specific regulations are laid down with respect to these ships, but it would be very desirable to have some set rules with respect to space, diet, and fittings. At present the diet, especially of invalids on board the hired transports, is not good. The invalids from India, landed at Netley, show not infrequently, Dr Maclean informs us, symptoms of scurvy. In respect of fittings, the use of swinging cots for feeble men, and well arranged closets for dysenteric cases, are very important. So also with the cooking; the coarse ship cooking is a great trial to many patients. If there is need of Government transports for healthy men, the necessity is still greater for sick men.

The general rules for transports are to be attended to here, with, of course, such relaxations and modifications as the state of the sick suggests. As far as possible, the sick should be treated on deck in fine weather, a good awning and a comfortable part of the deck being appropriated to them. I believe that it would be a good plan not to send home officers and sick men in the same ship, but to have officers' ships, so as to give up the poop to the men in the ships which carried them. This division would be a gain to both.

In time of war, sick transports are largely used to carry troops to hospitals in rear. For this purpose good roomy steamers must be chosen. For economy's sake, they will generally be large, and probably with two decks; they should never have more, and indeed a single deck is better. But if with two decks, each space should be separately ventilated by tubes, so as, as far as possible, to prevent passage of foul air from the lower to the upper deck. All the worst cases should be on the upper deck, especially surgical cases.

The decks of these vessels should be as clear as possible, so that men can be treated on deck. An apparatus should be arranged for hoisting men on deck from below.

It has been proposed to fit these ships with iron bedsteads, and no doubt this gives the men more space; but a better plan still would probably be to have short iron rods, to which every cot could be suspended. The sick men might be carried in their cots on board, and again removed. If the rods are made about 14 inches high, and bent in at the top so as to form a hook, a cot is hung easily, and will swing. There is space enough below to put a close-stool or pan under the man without stirring him, if a flap is left open in the canvas, and a hole left in the thin mattress.

Fixed berths are not so good, but some must be provided. Some cots can swing from the top, and some men can be in hammocks. Probably every sick transport should have all these, viz., iron bedsteads at some points fastened

to the deck, iron standards for swinging cots, cots swinging from the roof, low berths, and hammocks.

In these sick transports the kits and clothes must be stowed away; and as they are often very dirty and offensive, and sometimes carry the poison of typhus and other diseases, the place where they are put should be constantly fumigated with nitrous and sulphurous acid alternately. Robert Jackson mentions that dirty clothes and bedding may be soon washed sweet by mixing oatmeal with salt water.

Directly a sick transport has landed the sick, the whole place should be thoroughly washed and scraped, then the walls and ceiling should be lime-washed, and the between-decks constantly fumigated till the very moment when fresh sick embark.

SECTION III.

HOSPITAL SHIPS.

These are ships intended for the reception and treatment of the sick,—floating hospitals, in short. Whenever operations are undertaken along a seaboard, and especially when a force is moving, and places for fixed hospitals cannot be assigned, they are indispensable. They at once relieve the army from a very heavy encumbrance, and, by the prompt attendance which can be given to the sick, save many lives. They should always be organised at the commencement of a campaign. In the late Abyssinian war three hospital ships were used. Their fitting out was carefully superintended by Deputy-Inspector-General Dr Massy, and appears to have answered admirably. A full account of one of these ships ("Queen of the South") is given by Staff-Surgeon Chartres, to which reference may be made. The ventilation, as shown by the amount of carbonic acid (·708 per 1000 volumes) was very good.* The superficial space between decks per man was on the night of the experiment 154 feet, and the cubic space no less than 1076 feet.

However convenient, and indeed necessary, they are, it must be clearly understood that they are not equal to an hospital on shore. It is impossible to ventilate and clean them thoroughly. The space is small between decks. The wood gets impregnated with effluvia, and even sometimes the bilge is contaminated. I have been informed by Dr Becher, late pathologist in China, that even in the very best of the hospitals used there, it was quite clear that in every wound there was evidence of a slight gangrenous tendency. In fact, it is perhaps impossible to prevent this.

The principle of separation should be carried out in these ships—one ship for wounded men, another for fevers, a third for mixed cases; or if this cannot be done, separate decks should be assigned for wounded men and fever cases. In fine weather the sick should be treated on deck under awnings. The between-decks must be thoroughly ventilated, and all measures of fumigation, frequent lime-washing, &c., must be constantly employed. Charcoal, also, in substance should be largely used, and is, in fact, quite indispensable. Warming by stoves must be used in damp and cold weather, and, if so, advantage should be taken of this source of heat, and of all lights, to improve ventilation.

Ships of one deck are better than two; but as they will hold a very small number of sick, two decks are commonly used. But not more than two decks

* I have to thank Dr Woodward for allowing me to read his excellent Report on the Hospital ship "Mauritius," which was also employed in Abyssinia.

should be used; and if there be a third or orlop deck, it should be kept for stores. Sometimes, if there are two decks, the upper deck is used for officers and the lower for troops, but the reverse arrangement should be adopted.

The ventilation of the between-decks, in addition to Edmond's plan, should be carried on by tubes, which, if the central shaft is acting, will be all inlets, and can be so arranged as to cause good distribution of the air.

The fittings of an hospital ship should be as few and simple as possible, and invariably of iron. Tables should be small, and on thin iron legs. Swinging cots (as noticed in the former section) are indispensable for wounded men, and the appliances for the receiving and removing the excreta of dysenteric and febrile patients must be carefully attended to. Berths should not be of wood, but of iron bars, which are much more easily laid bare and cleaned.

The supply of distilled drinking water should be as large as possible, and a good distilling apparatus should be on board, whether the vessel be a steamer or not.

The laundry arrangements are most important, and I believe it would be a good plan, on a large expedition, to have a small ship converted entirely into a laundry. It would not only wash for the sick, but for the healthy men also. So also a separate ship for a bakery is an important point, so as to have no baking on board the hospital ship.

On board the hospital ship there should be constant fumigation; lime-washing, whenever any part of the hospital can be cleaned for a day or two, and, in fact, every other precaution taken which can be thought of to make the floating hospital equally clean, dry, well aërated and pure, as an hospital on shore.

On board hospital ships it is often easy to arrange for sea-bathing and douching; it should never be forgotten what important curative means these are.

In case pyæmia and erysipelas, or hospital gangrene occur, the cases must be treated on deck, no matter how bad the weather may be. Good awnings to protect from wind and rain can be put up.

If cows or goats are kept on board to supply milk, their stalls must be kept thoroughly cleaned. But generally it is better to obtain milk from the shore.

CHAPTER V.

WAR.

The trade of the soldier is war. For war he is selected, maintained, and taught. As a force at the command of a government, the army is also an agent for maintaining public order; but this is a minor object, and only occasionally called for, when the civil power is incompetent.

In theory, an army should be so trained for war as to be ready to take the field at literally a moment's notice. The various parts composing it should be so organised that, almost as quickly as the telegram flies, they can be brought together at any point, prompt to commence those combined actions by which a body of men are moved, fed, clothed, kept supplied with munitions of war, maintained in health or cured if sick, and ready to undertake all the engineering, mechanical, and strategical and tactical movements which constitute the art of war.

That an organisation so perfect shall be carried out, it is necessary that all its parts shall be equally efficient; if one fails, the whole machine breaks down. The strength of a chain is the strength of its weakest link, and this may be said with equal truth of an army. Commissariat, transport, medical, and engineering appliances are as essential as the arts of tactics and strategy. It is a narrow and a dangerous view which sees in war merely the movements of the soldier, without recognising the less seen agencies which ensure that the soldier shall be armed, fed, clothed, healthy, and vigorous.

During peace the soldier is trained for war. What is meant by training for war? Not merely that the soldier shall be taught to use his weapons with effect, and to act his part in that machine, where something of mechanical accuracy is imprinted on human beings, but that he shall also know how to meet and individually cope with the various conditions of war, which differ so much from those of peace.

It is in the nature of war to reinduce a sort of barbarism. The arts and appliances of peace, which tend, almost without our care, to shelter, and clothe, and feed us, disappear. The man reverts in part to his pristine condition, and often must minister as he best may to his own wants. No doubt the State will aid him in this; but it is impossible to do so as completely as in peace. Often, indeed, an army in war has maintained itself in complete independence of its base of supplies, and in almost every campaign there is more or less of this independence of action.

In peace, the soldier, as far as clothing, feeding, shelter, and cleanliness are concerned, is almost reduced to the condition of a passive agent. Everything is done for him, and all the appliances of science are brought into play to save labour and to lessen cost. Is this the proper plan? Looking to the conditions of war, ought not a soldier to be considered in the light of an emigrant, who may suddenly be called upon to quit the appliances of civilised life, and who must depend on himself and his own powers for the means of comfort, and even subsistence?

There is a general impression that the English soldier, when placed in unaccustomed circumstances, can do nothing for himself, and is helpless. If so, it is not the fault of the man, but of the system, which reduces him to such a state. That it is not the fault of the man is shown by the fact that, however helpless the English soldier may appear to be in the first campaign, he subsequently becomes as clever in providing for himself as any man. The Crimean war did not perhaps last long enough to show this, but the Peninsular war proved it. The soldier there learned to cook, to house himself, to shelter himself from the weather when he had no house, to keep himself clean, and to mend and make his clothes. Was it not the power of doing these things, as well as the mere knowledge of movements and arms, which made the Duke of Wellington say that his army could go anywhere and do anything? And the wars at the Cape and in New Zealand have shown that the present race of soldiers, when removed from the appliances of civilised life, have not lost this power of adaptation.

The English soldier is not helpless; he is simply untrained in these things, and so long as he is untrained, however perfect he may be in drill and manœuvre, he is not fit for war. The campaign itself should not be his tutor; it must be in the mimic campaigns of peace, in which the stern realities of war are imitated, that the soldier must be trained. Our present field-days represent the very acme and culminating point of war; the few bright moments when the long marches and the wearisome guards are rewarded by the wild excitement of battle; but the more common conditions of the campaign ought also to find their parallel. Since the Crimean war, much has been done to instruct the soldier in the minor arts of war. The establishment of camps has to some extent familiarised him with tent life; the flying columns which go out from Aldershot show him something of the life of the bivouac, and the training in cooking which Lord Herbert ordered is teaching him how to prepare his food. It requires only an extension of this system to make the soldier familiarised with the chief conditions of the life in campaigns.

A campaign can never be successful unless the men are healthy. How are men to be trained so as to start in a campaign in a healthy condition, and to be able to bear the manifold trials of war? The answer may be given under three heads—

1. Preparation for war during peace.
2. Entry on war.
3. Actual service in war.

SECTION I.

PREPARATION FOR WAR DURING PEACE.

The various conditions of war, which are different from those of peace, are—

1. *Exposure to the Weather.*—It is a constant observation that men who have led out-door lives are far more healthy in war than men whose occupations have kept them in houses. The soldier's life should be, therefore, an out-door one. This can only be done properly by keeping him in tents during the summer. It would be well, in fact, to tent the whole army from the middle of May to the end of September every year. The expense should be looked on as a necessary part of the military establishments. Wooden huts are too like ordinary barracks. As the soldier has often to sleep out in war, he should be accustomed to this also in peace; warm summer nights being

first selected to train him. It will soon be found that he will very soon acquire the power of resistance to cold. This plan also will test the utility of his clothes.* It has been found by experiment that, by careful training, even delicate persons can bear sleeping out at night, even in tolerably cold weather, without injury, provided there be no rain. At the latter end of the summer it would be well to expose the men even to rainy nights, their clothes being adapted for this by the supply of waterproofs.

At the same time, it is important to have the men raised off the ground, both when in tent and lying in the open air, in all countries where the ground may be moist or cools rapidly during the night. A very useful field hammock has been invented by Captain M[cc]Quire; it consists of a strong woollen material, which is suspended on two sticks by means of guide-ropes. It makes a comfortable bed, and keeps the body very warm.

It may be thought that training of this kind is needless, and that it may be left to the campaign to accustom the men to exposure, but this is not the case; a number of men are rendered inefficient at the commencement of a campaign simply by the unaccustomed exposure.

2. *Tent and Camp Life.*†—The pitching, striking, and cleansing of tents (see page 324); the digging trenches round the tents, and providing for general surface drainage; the arrangement of the interior of the tent, &c., should all be carefully taught. So also the camp life of the campaign should be closely imitated. A place being taken up for the camp, and if there be any prevailing wind, the front of the camp being turned to the wind, dry paths should be constructed between the different roads; latrines should be dug in rear of the stables, and not too near the kitchen, and *en échelon* with the camp; each latrine should be a trench twenty to fifty feet long, according to the size of the camp, ten deep and two wide at the top, and three at the bottom. The earth thrown out should be arranged on three sides. It should be screened by branches of trees, and earth should be thrown in every day. When four feet from the surface, it should be filled in and another dug, the earth of the old one being raised like a mound to mark the spot. Close to it an urinal should be constructed, of a sloping channel paved as well as it can be, and leading into the latrines, or of a tub which can be emptied into it, and, as far as possible, men should be prevented from passing the urine round their tents.

A corps of scavengers should be immediately organised to clean away all surface filth, and to attend to the latrines and urinals. All refuse must be completely removed; it is often a good plan to burn it. Both in peace and war, encamping ground should be often changed, and an old camp should never be occupied. (For erection of Huts, see page 320.)

In addition to tents, the men should be taught, if possible, to house themselves. Huts of wattle should be run up, or wooden sheds of some kind. In war, men soon learn to house themselves. Luscombe‡ gives the following account of the huts in the Peninsula:—

"A cork tree or evergreen oak with wide-spreading branches was chosen; a lower branch was nearly cut through, so as to allow the extreme points to

* In reference to what was said (p. 417) of the great importance of a hood to the greatcoat for men who sleep out at night, an old observation of Donald Monro is of interest. He states that in 1760 the greater health enjoyed by the Austrian Hussars over other troops was owing to the half-boots, and the large cloaks with hoods carried by these men.—*On the Means of Preserving the Health of the Army* (2d edit. 1780, p. 7).

† I may refer here for fuller details to some excellent treatises on Camps lately published in Germany and Russia, especially by Dr Roth (Das Zeltlager auf der Lockfstädter Heide in Holstein, 1866), and by Dr Heyfelder (Das Lager auf der Krasnoe-Selo, 1868.)

‡ On the Means of Preserving the Health of Soldiers, 1821, p. 107.

drop to the ground. Other branches were then cut from adjoining trees and fixed in a circle in the ground, through the branch, on which their upper branches rested. Smaller branches were then interwoven to thicken the walls, and the inside was lined with the broom-plant, which was thatched in. The door of the hut was put due east, so that the sun might pass over it before it reached the horizon.

This hut was very cool during the day, but *very cold* at night, and thus "very prejudicial to health."

Underground huts are sometimes used; they are, however, dangerous; they are often damp, and are difficult of ventilation. In cold, dry countries, however, they are warm, and the Turks have constantly used them in campaigns in winter on the Danube. They have, however, frequently suffered from typhus. If used, there should be two openings besides the chimney, so as to allow a current of air; and a spot should be chosen where it is least likely water will gravitate. But underground huts are always to be discouraged if any substitutes can be found. Sometimes the side of a hill is cut into, and the open top covered with boards and earth. This is as bad as an underground hut.

Tents should not be placed in an excavation, but, if too cold, a wall of stones or earth should be built, and the tent placed on it. When sleeping out, the men should be taught to use every inequality of the ground as a protection against cold winds; it is astonishing what protection even a slight elevation gives.

3. *Cooking of Food.*—No doubt, in future wars, all governments will endeavour to supply prepared and cooked food (see page 244), so as to lessen the cost of transport and the labour of the soldier. But as this cannot always be depended upon, the soldier must be trained to cook his ordinary rations. This should not be done for him; he ought to do it himself merely with the appliances he would have in war, viz., his camp kettle, canteen, and tin plate.

The camp kitchen is simply a round or square hole, sunk half a foot to a foot in the ground; the fire is fed with air by a small channel cut in the ground for some little distance. This channel should be covered in with turf or stones, and by proper management the draught to the fire can be increased or lessened; if the fire itself be more or less covered with a stone, or tin plate, or turf, the fuel can be economised. The fire can be used for boiling, or for baking in the canteen; the fire being then taken out, or the embers heaped round the sides, and the top closed or nearly so.

At the commencement of a campaign many men lose flesh and strength from the food being badly cooked and indigestible.

In the Peninsular war the men became admirable cooks. At first very large camp-kettles, intended for half a company, were used, and were carried on horses. They did not answer, and the men left them behind. Afterwards smaller camp-kettles were supplied, one for each mess of six or eight. Luscombe mentions that the supply of salt was found to be a very important point; he says, he had no idea of the value of this condiment till he saw the way in which the men saved every little particle; without it, in fact, animal and even vegetable food is unsavoury.

It may be a question whether the present canteen might not be improved; it should not be soldered. No soldered articles do in war; the solder melts, and cannot be replaced. Many years ago a very portable cooking tin was sold in shops in London; it would hold a pint of water, which could be boiled by lighting a comparatively small piece of brown paper, placed in an outer casing, and slowly supplied with air. The objection to any articles of this kind is the weight.

In the Crimea some camp stoves, invented or improved by Soyer, were used. Such things are very useful in camps of position, but are not always forthcoming in rapid movements.

In the French army on service 8 or 10 men form a corporal's detachment, or "escouade." They have between them one kettle and cover (*marmite*, weight 1·7 kilog.), one large bowl (*grande gamelle*, weight 1 kilog.), and one large drinking vessel (*grand bidon*, weight 1·5 kilog.) Each man has for his personal use a small bowl (*petite gamelle*), and a small drinking vessel (*petit bidon*). They are all of tinned iron. All these vessels are carried by the men, the larger vessels being taken in turn by the men of the mess.

It may be concluded with regard to this very important matter of cooking utensils, that a man should have a small but very strong canteen, made of unsoldered tin, and with a good deep lid, with a handle which may serve as a frying-pan or second vessel, as well as a cover. The shape of the canteen should be long and flat, and not deeper than is necessary for cooking, so that it may be easily carried. Then all the other vessels, the camp-kettles for each mess, and the large water vessels, should be carried for the men. They should be made of thin steel, which is very light for its strength, very durable, and is not acted on by the food.

The different kinds of camp cooking to be taught are stewing, boiling, and making soup, making tea and coffee, cooking preserved vegetables, making cakes of flour, and oatmeal porridge.

4. *Water Supply.*—As impure water is a great cause of sickness in war, the soldier should be taught how to recognise impurity, and how to use the simple methods of purification with charcoal, alum, tea, boiling, &c. (See chapter on WATER.)

5. *Mending Clothes.*—Every soldier carries a hold-all, but many cannot use it properly. It may be suggested whether, in the workshops which are now being established, it would not be well to let every recruit have a month's practice in repairing clothes, and especially boots; simple plans of repair being selected if it be possible.

6. *Cleanliness.*—In war a source of disease is the want of cleanliness. Very soon the person and clothes get covered with lice; all the garments, outer as well as under, get impregnated with sweat, and become very filthy. The best generals have always been very careful on this point, and have had frequent washing parades. As washing clothes is really an art, the soldier should be taught to do it, not by machinery, but in the rude fashion he must practise during war. Clothes can be partially cleaned by drying and beating.

The hair should be cut short. In the absence of water for washing, the best plan is the small-tooth comb, to keep the hair free from vermin, and it may be a question whether one should not be supplied to every soldier.

Washing the whole body in cold water, whenever it can be done, is not only bracing and invigorating, but strengthens it against vicissitudes of weather, and against dysentery.*

SECTION II.

ENTRY ON WAR.

When actual war commences some further steps become necessary.

All experience shows that men under twenty or twenty-one years of age

* Both Donald Monro and Lind notice this.

cannot bear the fatigues of war.* If possible, then, all men below twenty-one, or at any rate below twenty, should be held back from the campaign, and formed into depôts, whence they may be draughted for active service on occasion. Of course every means should be taken during their service at the depôts to strengthen and harden them.

All weakly men should also be held back, and every man thus retained should come under the surgeon's superintendence, not in hospital, but while doing his duty.

The men who are about to enter on the campaign should at once commence a more severe training. If there be time to do it, this should be carried to an extent even greater than will be demanded in war, in the manner of the Romans, who trained their soldiers so severely in peace that war was a relief. The rules given in marches about sore feet, and the means of preventing those and other evils, should be attended to (see page 400, *et seq.*) at this time.

Certain changes in the food of the men should be made.

The exertions of war, bodily and mental, are often very great, and demand an increased quantity of food, especially in the nitrogenous and fatty elements; an increased amount of meat and bread, with the addition of fat bacon, cheese, and peas or beans, should be given, so as to bring the daily amount of nitrogen to 400 grains, and of carbon to 5000 or 6000 grains daily, or, in other words, 6 ounces of albuminates (= 400 grains of nitrogen and about 1400 grains of carbon), 3 ounces of fats (= 1137 grains of carbon, and about 14 ounces of carbo-hydrates (= 2702 grains of carbon). The salts also must be increased, and it would be well to do this by adding chloride of potassium, phosphate of soda, and perhaps a little citrate of iron to the culinary salt. During the war, make every effort to get bread and flour supplied in lieu of biscuit, and to supply red wine (page 261).

As one of the perils of war is the occurrence of scurvy, the supply of fresh vegetables should be increased; if these at all fail during the campaign, the preserved vegetables must be issued, and the other precautions taken (see pages 288 and 492). Considering the benefit apparently derived in Captain Cook's voyages from wort made from malt, it might be worth while to try the effect of introducing this as a beverage; it can be readily made.

Donald Monro mentions that at Bremen, in 1762, when no vegetables could be got, and fresh meat was dear, and scurvy broke out, infusion of horse-radish was found to be useful. Spruce beer was also used. The concentrated foods should also be largely stored, so that the troops can be supplied on excursions or in emergencies, and the men should be taught how to cook them, and especially in the case of compressed vegetables.

SECTION III.

ACTUAL WAR.†

Experience has showed in hundreds of campaigns that there is a large amount of sickness. The almost universality of this proves that, with every care, the conditions of war are unfavourable to health. The strenuous exer-

* The examples are numerous, but the following are often quoted. In 1805 the French army broke up at Boulogne, and marched 400 leagues (French) to fight at Austerlitz; the youngest soldier was twenty-two years old; they left scarcely any sick or wounded *en route*. In 1809 the French marched from the German provinces to Vienna; not half the army were aged twenty years; the hospitals were filled with sick. In 1813 and 1814 the despatches of Napoleon are filled with complaints of the "boys" who were sent him, and who died in multitudes by the road side and in the hospitals.

† *Sanitary Rules of the Romans during War.*

Vegetius (*De Re Militari*, lib. iii. cap. 2) says the Romans took great care that the men

tions, the broken rest, the exposure to cold and wet, the scanty, ill-cooked, or unwholesome food, the bad water, and the foul and overcrowded camps and tents, account for the amount of disease.

The amount of illness varies with the nature of the campaign and the genius of the commander.

If records can be trusted, it would seem that the English have been more unhealthy than the French in their wars, but there is no great trust to be placed in war statistics. In the Peninsula the mean daily number of sick was never below 12 per cent., except for a short time, in the lines of Torres Vedras, when it fell to 9 or 10. Sometimes it amounted to 15, 20, or 25 per cent. In the Crimea the immense sickness of the first winter is but too well remembered.

Army Medical Regulations.

Before an army takes the field, the Director-General may appoint a medical officer to act as Field-Inspector under the principal medical officer, but not to act as sanitary officer. The Director-General prepares lists of all medicines, stores, &c. The amount of transport and of stores is laid down.

Before an army takes the field, the Director-General, on requirement by the War Office, gives an account of everything in the proposed scene of operations which may affect the health of the men. He appoints a sanitary officer to be attached to the Quartermaster-General's department. He issues instructions to the principal medical officer and sanitary officer on all matters connected with rations, clothing, shelter, precautions for preventing disease, &c.

The sanitary officer inspects all proposed encamping ground, quarters, &c., and supervises the sanitary arrangements of all camps, towns, hospitals, &c. The principal medical officer advises the Commander of the Forces on all matters affecting health, such as rations, shelter, clothing, &c., and may, with the sanction of the Commander of the Forces, issue instructions on such matters to the medical officers.

The sanitary officer inspects the camp daily; accompanies the Quartermaster-General on the march, and gives his advice on all sanitary points. He is supplied with information to aid him in his work from all principal medical officers of general hospitals, divisions, and brigades in the field. He transmits a weekly sanitary report to the principal medical officer.

Causes of Sickness and Mortality in War.

The chief causes of sickness and mortality in the English army have been in order of fatality—

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should be well supplied with good water, good provisions, firewood, sufficient quantity of wine, vinegar, and salt. They endeavoured to keep their armies in good health by due attention—

1. To Situation; avoiding marshes and dry uncovered ground in summer; in having tents; frequently changing camps in summer and *autumn*.
2. To the Water; for bad water was considered to be very productive of diseases.
3. To the Seasons; not exposing men to heat. In winter, taking particular care that the men never were in want of firewood or of clothing.
4. To Food and Medicine; the officers saw that the men had their regular meals, and were well looked after by the commissariat.
5. To Exercise; by keeping the troops during the day-time in constant exercise; in dry weather in the open air; in time of rain or snow under cover; for exercise was believed to do a great deal more for the preservation of health than the art of physic.

The Præfectus-Castrorum (Quartermaster-General), an officer of high rank in the Roman army, looked after the sick, and provided everything required by the surgeons. Both Livy and Tacitus mention that the commanding officers used to visit the sick and wounded soldiers, to inquire if they were well taken care of.

Rules of the Macedonians.—The only notice, I believe, of the means by which Alexander the Great preserved so wonderfully the health of his small army, is a statement that he frequently changed his encamping grounds (Quintus Curtius, lib. v. 32). This great soldier must certainly have been acquainted with the art of Hygiene.

1. Diseases arising from improper and insufficient food, viz., general feebleness and increased liability to malarious fevers, dysentery, diarrhœa, &c., and production of scurvy and scorbutic dysentery.

2. Malarious disease from unhealthy sites.

3. Catarrhs, bronchitis, pleurisy, pneumonia, rheumatism, dysentery (?), produced by inclemencies of weather.

4. Spotted typhus, kept up and spread (if not produced) by overcrowding and uncleanliness.

5. Contagious dysentery, arising from foul camps and latrines.

6. Typhoid and perhaps other fevers, produced by foul camps.

7. Exhaustion and debility, produced by excessive fatigue—a very great predisposing cause of almost all other diseases.

8. Cholera, in India especially, and in Turkey.

9. Yellow fever in the West Indian campaigns.

10. Plague in Egypt.

11. The exanthemata occasionally.

12. Ophthalmia.

13. Venereal diseases.

Of these diseases the most fatal have been scorbutic dysentery and typhus. It is indeed curious to see how invariably in all wars the scorbutic taint occurs, and frequently in how early a period of the campaign it can be detected. There almost seems to be something in the fatigues and anxieties of war which assists its development. It frequently complicates every other disease, impresses on them a peculiar character, and renders them very intractable to treatment. This is the case with dysentery, typhoid fever, malarious fever, and spotted typhus. With the last disease, especially, it has intimate relations, and contributes apparently to its propagation by rendering the frame more easily attacked by the specific poison.

One of the most important preventive measures to be adopted in war is the prophylactic treatment of scurvy. But with a full knowledge of this, the disease cannot always be avoided. The Federal Americans were fully aware of the necessity of combating it, and made immense efforts to do so. They did not succeed, and so marked and so general was the scorbutic taint in their army, that its combinations with typhoid fever and malaria have been looked upon as new diseases.

If scurvy could be prevented, every other war disease would be comparatively trifling. Inflammations from exposure, exhaustion from fatigue, and gastro-intestinal affections from improper food and atmospheric vicissitudes, would still occur; but the ravages of typhus, typhoid fever, malaria, and dysentery, would be trifling and easily prevented.

To prevent scurvy, then, is one of the most important measures.

If scurvy be absent, typhus fever is readily treated; isolation and the freest ventilation are certain to stop it. The only great danger would be in a besieged and crowded fortress. In such a case it may be beyond control, but early recognition and prompt isolation, as far as it can be done, and as free ventilation as possible, may perhaps stop it. It is in such cases that we should freely use the nitrous acid fumes and other disinfectant vapours.

Enteric typhoid fever and contagious dysentery, in the same way, ought with certainty to be prevented in a camp. The first case, even, should make us take urgent measures for the cleansing of latrines, or, better still, the closing of all the old and the opening of fresh ones. But the best plan of all is to shift the encamping ground, and we should remember the old Roman maxim, based doubtless on observation of typhoid fevers, that this must be done more often in the autumn.

The exanthemata, measles, and scarlet fever, sometimes spread largely through an army; the only plan is to separate all cases, and send them one day's march on the flank of the army, if it can be done, not in the direction of the line of supplies.

Plague probably demands the same measures as typhus.

The measures for cholera have been already sufficiently noted.

The diseases of exposure can be hardly avoided, but may be lessened by warm clothes and waterproof outer coverings. Flannel should be used next the skin all over the trunk and extremities, and is indispensable. One of the most important means to enable troops to stand inclemencies of weather, and indeed all fatigues, is hot food. Coffee and tea are the best, and hot spirits and water, though useful as an occasional measure, are much inferior, if indeed they do any good at all apart from the warmth. But the supply of *hot* food in war should be carefully attended to, especially in the case of breakfast, after which men will undergo without harm great exposure and fatigue.

It is unnecessary to enter at greater length into the measures to prevent the diseases of war, for the proper plans have been all enumerated previously. We may conclude only that much can be done to prevent disease, but we must also remember that the course of campaigns sometimes is too violent and overpowering for our efforts, and that wars, like revolutions, will never be made with rose-water.

Recapitulation of the Duties of a Sanitary Officer during War.

To go forward with the officers of the quartermaster's department, to choose the camping ground; arrange for surface drainage; if necessarily in a malarious place, make use of all obstacles, as hills, trees, &c., to throw off the malaria from the tents; place the tents with the openings from the malarious quarter. If possible, never take low hills (100 to 250 feet) above marshy plains. Arrange for the water supply, and for the service of the men, animals, and washing. As soon as possible fix the sites for the latrines; have them dug out, and make dry paths to them. As soon as the tents are pitched, visit the whole camp, and see that the external ventilation is not blocked in any way, and that the tents are as far off each other as can be permitted. Assign their work to the scavengers, and mark out the places of deposit for refuse. The daily inspection should include all these points, as well as the inspection of the food and cooking and of the slaughter-houses. If the camp be a large one, a certain portion should be selected every day for the careful inspection of the individual tents, but it should be made in no certain order, that the men may not prepare specially for the inspection.

A set of rules should be drawn up for the men, pointing out the necessity of ventilation, cleanliness of their persons, tents, and ground around them, and ordering the measures which are to be adopted. This will have to be promulgated by the general in command.

In the daily work, a certain order and routine should be followed, so that nothing shall be overlooked.

The sanitary officer of a large camp can never perform his duties without the most unremitting support from the regimental medical officers, who are the sanitary officers of their regiments. Not only must they inspect their own regimental camps, but by an immediate report to the sanitary officer of any disease which can possibly be traced to some camp impurity, they should render it possible for the commencing evil, of whatever kind, to be detected and checked.

As early as possible every morning the number of men reported sick from

each regiment should be made known, and a calculation made of sick to strength, and then, if any regiment showed any excess of sick, the sanitary state of its camp should be specially and thoroughly investigated.

*Hospitals in War.**

With an army in the field hospitals are of several kinds.

1. *Regimental Hospitals.*—These are purposely kept as small as possible; they are intended merely to receive the men when they are first reported sick, and to treat the slightest cases. But it is most important to keep the regiment free from sick men, and any man who is likely to be ill for several days should be sent to the hospitals in rear. At the same time, the existence of regimental hospitals is essential; they have their special advantages, and general hospitals can no more take their place than they can prevent the need of general hospitals.

2. *Division Hospitals* are small general hospitals under the charge of a staff-surgeon and staff assistant-surgeon. They are intended especially for emergencies, such as wounded men in action, and should be kept as empty as possible for this purpose; still, sometimes they must be used for urgent medical patients who are too ill, or attacked too suddenly, to be sent to the hospital in rear; or if the hospital in rear is at some distance, they are used as receiving houses. Both regimental and division hospitals move with the force, and are best made of tents. The tents should be large, and thoroughly ventilated. The present hospital marquee is a very good one. It is now quite certain that good well-ventilated tents are much better than any buildings which can be got.

3. In rear of the army is the *Field General Hospital*, which receives all the sick and wounded who can be transported from the front. The exact position of this hospital depends on the campaign and country. It is put as near to the army as it can be, regard being had to the safety of the men and the necessity of supply of hospital stores. The Austrian experience seems to be in favour of making it of tents, moving it up with the army. It must be of great advantage to have it made of tents; they have all the advantage of separate houses both as to ventilation and separation of patients; have excellent ventilation, if well made; can be shifted from ground to ground or place to place; erysipelas and hospital gangrene are extremely rare in them.

In the General Hospital, classification of patients is of extreme importance, and this can be more easily managed by tents or wooden huts than in any other way. Surgical cases must be kept separate; on no account must they ever be put with fever cases. This was a Peninsular rule of Sir James M'Grigor, and should never be forgotten. The fever cases (if admitted), both typhus and typhoid, should be by themselves, and ophthalmic cases must also be isolated. There may be more admixture of other diseases.

4. In rear, again, of the Field General Hospital, other hospitals intended for lingering cases, for half-cured wounds, all cases of severe inflammations which can be moved, rheumatism, phthisis, fever cases, &c., and men requir-

* Sir James M'Grigor, in the Peninsula, established divisional hospitals in front, and convalescent hospitals in the rear, where the men were received *en route* to the depôt. Although he does not describe his system fully in his paper in the Medico-Chirurgical Transactions (vol. vi.), it is evident from his Autobiography that his constant practice was to send off the sick as soon as possible. This is shown by his narrative of the retreat from Burgos, when he saved Lord Wellington from the mortification of abandoning his sick and wounded to the enemy. In this section I have merely enumerated the hospitals and considered them from a hygienic point of view. My colleague, Professor Longmore, in the work on Transport, which has just been published, has detailed at length the means of transport of the sick and wounded, and other important matters of the kind.

ing change of air, must be organised. These may be at some distance in rear, but connected either with a railway or by water carriage. It is of great importance to keep continually sending patients from the division and general hospitals with the army to the hospitals in rear. It is not only to keep the hospitals in front empty for emergencies, and to facilitate all movements of the army, but it has a great effect on the army itself. A great hospital full of sick is a disheartening spectacle, and often damps the spirit of the bravest men. The whole army is higher in hope and spirits when the sick are removed, as was shown remarkably by the Austrian experience of 1859. The sick themselves are greatly benefited by the removal; the change of scene, of air, of ideas, has itself a marvellous effect, and this is another great reason for constantly evacuating the sick from the hospitals in front.

The men who are reported for hospital in war must be divided into several classes :—

1. Slightly wounded should be treated in the regimental or division hospitals, and then return to duty.
2. Severely wounded at first in the division hospitals, then sent to the general hospital, and then to the rear, as convalescence is always long.
3. Slight colds, diarrhœa, &c., treated in the regimental hospitals.
4. Severer colds, bronchitis, pleurisy, pneumonia, dysentery, &c., should be sent at once to the general hospital, and then to the rear as soon as they can move with safety.
5. Typhus fever at once to the hospitals in rear, if possible without entering the field general hospital.
6. Typhoid cases, also, should be sent to the rear, and, in fact, all severe cases. The field general hospital should be always almost empty, and ready for emergencies.

These hospitals in rear may be even two to three days' journey off, if conveyance be by water, or one or two days if by rail. Sick and wounded men bear movement wonderfully well with proper appliances, and are often indeed benefited.*

The proper position for these hospitals, at the base of operations, must be fixed by the commander of the forces at the commencement of a campaign, as he alone will know what point will be the base of supplies, and it is of importance to have these great hospitals near the large stores which are collected for the campaign.

It seems now quite clear that these hospitals should not be the ordinary buildings of the country adapted as hospitals. Such a measure seldom succeeds, and the mere adaptation is expensive, though probably always imperfect.† Churches should never be taken, as they are not only cold, but often damp, and there are often exhalations from vaults.

The French, Austrian, and American experience is in favour of having the hospitals in rear made of tents or wooden huts. The huts are perhaps the best, especially if the winter be cold. They have been very largely used by the Federal Americans, who have entirely given up converting old buildings into hospitals. The best huts which were used in the Russian war of 1854–56 were those erected at Renkioi from Mr Brunel's design; each held fifty men in four rows. This plan, however, is not so good a one as having

* On this and other points of the like kind, see Report on Hygiene, in the "Army Medical Report for 1862," pp. 349, 350.

† Donald Munro says that, in 1760, the houses in Germany taken for the sick were improved by taking away the stoves and putting in open fire-places. In the Peninsula, the Duke of Wellington appeared to have a dread of fever attacking the army. Luscombe tells us that the Duke asked the principal medical officer every day as to the appearance of fever. He also improved the hospitals by ordering open fire-places.—*Luscombe*, p. 6.

only two rows of beds. Hammond* states that in the American war the best size has been found to be a ward for fifty men with two rows of beds; length of ward, 175 feet; width, 25 feet; height, 14 feet; superficial area per man, 87 feet; cubic space per man, 1200 feet. Ventilation was by the ridge, an opening 10 inches wide, running the whole length, and by openings below, which could be more or less closed by sliding doors. Some of the American hospitals held from 2000 to 2800 beds.† It is probable, however, that smaller wards (for 25 men) would be better.

An hospital constructed of such huts can be of any size, but there must be several kitchens and laundries if it be very large. If space permit, however, it seems desirable to have rather a collection of smaller hospitals of 500 beds each, separated by half a mile of distance, than one large hospital.

The arrangement of the huts must be made according to the principles already laid down. Dr Hammond writes thus of these hospitals :—

"It will, perhaps, not be out of place again to insist on the great advantages of these temporary field hospitals over those located in permanent buildings in towns. Nothing is better for the sick and wounded, winter and summer, than a tent or a ridge-ventilated hut. The experience gained during the present war establishes this point beyond the possibility of a doubt. Cases of erysipelas or of hospital gangrene occurring in the old buildings, which were at one time unavoidably used as hospitals, but which are now almost displaced for the ridge-ventilated pavilions, immediately commenced to get well as soon as removed to the tents. But in one instance that has come to my knowledge has hospital gangrene originated in a wooden pavilion hospital, and in no instance, as far as I am aware, in a tent. Hospital gangrene has been exceedingly rare in all our hospitals, but two or three hundred cases occurring among the many wounded, amounting to over 100,000 of the loyal and rebel troops which have been treated in them. Again, wounds heal more rapidly in them, for the reason that the full benefit of the fresh air and the light are obtained. Even in fractures the beneficial effects are to be remarked." ("On Hygiene," p. 397.)

Baron Larrey, in his useful work,‡ describes the plans adopted by the French in the Italian war of 1859. At Constantinople, during the Crimean war, the French were apparently very well installed; the best buildings in Constantinople were assigned to them, and they were arranged with all the accuracy of organisation which distinguishes the French. The results were not, however, favourable, especially in the spring of 1856, when typhus spread through many of the hospitals, and caused great mortality.§ Taught by this experience, in the Italian war of 1859 the French distributed their sick in small hospitals whenever they could find a building, and in this way the extension of the specific diseases was entirely stopped.

To sum up, the hygiene of field hospitals in war (the rules are derived from our own Crimean experience, and that of the wars which have taken place

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* On Hygiene, p. 355.

† See Report on Hygiene, in the Army Medical Report for 1862, p. 345, *et seq.*, for a fuller description.

‡ Notice sur l'Hygiène des Hopitaux Militaires, 1862.

§ Larrey mentions some striking instances of the effects of overcrowding. At Rami-Tchifflick, the hospital was fixed for 900 by the surgeon in charge, who allowed no more; it remained healthy. His successor increased the beds to 1200 and then to 1400. Typhus became most severe, and spared no one (ni infirmiers, ni sœurs, ni médécins). In the hospital at Pera there was the same mistake, and the same results. Typhus caused fifty per cent. of the deaths. At the hospital of the École Militaire no crowding was permitted, and typhus caused only ten per cent. of the deaths. In the French ambulances in the Crimea the same facts were noticed. Double and treble numbers were crowded into some, and they were ravaged by typhus; others were not allowed to be crowded, and had little typhus.

since) is as follows :—The movable field hospitals (regimental, division, and general, in rear) to be made of tents; the tents being well constructed, of good size, thoroughly ventilated, the flaps being able to be raised so as almost, if desired, to make the tent into an awning.

The ground round the tents to be thoroughly drained, kept very clean, and replaced from time to time. The tent floor to be covered with clean, and, if possible, *dried* earth, or charcoal, and to be then covered with a waterproof cloth, or boarded, if the camp be one of position. In either case the greatest care must be taken that the ground does not get soaked and filthy. Every now and then (if possible every ten days or so) the tents should be shifted a little.

If it can be done, the sick should be raised off the ground. Iron bedsteads are cumbrous, but small iron pegs stuck in the ground might carry a sort of cot or hammock. The advantage of a plan of this kind is, that by means of holes in the sacking, wounded men can have the close-stool without much movement. For fever cases it permits a free movement of air under the patient.

The stationary general hospitals in rear should be of tents or wooden huts, but never of converted buildings, or of hospitals used by other nations. Here, of course, iron bedsteads, and all the appurtenances of a regular hospital, are brought into play.

Whenever practicable, the rear hospital should have water-closets and sewers. At Renkioi, in Turkey, Mr Brunel supplied square wooden sewers about fifteen inches to the side; they were tarred inside, and acted most admirably, without leakage, for fifteen months, till the end of the war. The water-closets (Jenning's simple syphon), arranged with a small water-box below the cistern to economise water, never got out of order, and in fact, the drainage of the hospital was literally perfect. I have little doubt such well-tarred wooden sewers would last two or three years.

There is one danger about wooden hospitals, viz., that of fire. The huts should, therefore, on this ground alone, be widely separated; each hut should have, about ten feet from it, an iron box for refuse. Wooden boxes do not answer, as in the winter live cinders get thrown in, and there is danger of fire. These boxes should be emptied every morning by the scavengers. Water must be laid on into every ward.

The arrangement of the buildings is a simple matter, but must partly be determined by the ground. Long open lines are the best. An hospital of this kind, completely prepared in England, can be put up at a very rapid rate, supposing there be no great amount of earth-work, and that the supply of water and of outlet for sewage be convenient. So that, if commenced at once at the beginning of a campaign, accommodation would soon be provided.

If tents be used for the hospital in rear, they should be much larger than those of the movable hospitals.

Laundry Establishment.

This part of an hospital must be organised as early, and as perfectly, as possible. The different parts must be sent out from England, viz., boiler, drying-closet, washing-machines, and wringing-machines. The washing in war can never be properly done by the people among whom the war is carried on. Every appliance to save labour must be used, and after calculating what amount of laundry work has to be done for a presumed number of sick, just twice the amount of apparatus should be sent out, partly to ensure against breakage, partly to meet moments of great pressure. The drying-closet, especially, is a most important part of the laundry, as its heat can be used to disinfect.

Amount of Hospital Accommodation.

This must not be less than for 25 per cent. of the force, with reserve tents in rear in case of need.

Cemeteries in war must be as far removed as possible; the graves dug deep, and peat charcoal thrown in if it can be procured. Lime is generally used instead, but is not quite so good. If charcoal cannot be got, lime must be used. If the army is warring on the sea-coast, burial in the sea is the safest plan.

Flying Hospitals.

For moving columns and excursions, flying hospitals are organised. Medical comforts, concentrated foods, wine, brandy, dressing instruments, bedding, &c., and perhaps tents, are carried in light carts, or on mules, or camels. If it can be done, an old recommendation of Donald Monro seems useful, viz., that a baker with flour should accompany, and even a butcher with live stock; but since the use of concentrated foods, the last is perhaps less needed.

Sanitary Duties connected with a War Hospital.

In addition to the usual sanitary duties of an hospital, there are one or two points which require particular attention in the field.

The first of these is the possible conveyance of disease by the exceedingly dirty clothes, which may perhaps have been worn for weeks even, without removal, in the hard times of war. Typhus, especially, can be carried in this way.

To provide for this, every hospital should have a tent or building for the reception of the clothes; here they should be sorted, freely exposed to air, and the dirty flannels or other filthy clothes picked out. Some of these are so bad that they should at once be burnt, and the principal medical officer, at the beginning of a campaign, should have authority given him to do this, and to replace the articles from the public store.

The articles which are not so bad should be cleansed. The cleansing is best done in the following way:—If the hospital have a laundry and drying-closet, they should be put first in the drying-closet for an hour, and the heat carried as high as possible, above, if it can be, 240° Fahr. Then they should be transferred into the fumigation box; this is simply a tin-lined box or large chest. The clothes are put in this, and sulphur placed above them is set on fire, care being taken not to burn the clothes; or nitrous acid fumes should be used. After an hour's detention in the fumigating box they should be removed to the soaking tubs. These are large tubs with pure water, put in a shed or tent outside the laundry. A little chloride of lime can be added to the water. They should soak here for 24 hours, and then go into the laundry and be washed as usual. This plan, and especially the heating and fumigation, will also kill lice, which often swarm in such numbers.

Another point of importance is to bathe the men as soon as possible. The baths of a war hospital at the base of operations should be on a large scale, and the means for getting hot water equally large. The men's heads, if lousy, should be washed with a little weak carbolic acid, which kills the lice at once. The smell is not agreeable, but that is not of real consequence.

In a war hospital, also, the use of charcoal in the wards, charcoal dressings, the employment of disinfectants of all kinds, is more necessary than in a common hospital.

As a matter of diet, there should be a large use in the diet of antiscorbutic food, vegetables, &c., and antiscorbutic drinks should be in every ward, to

be taken *ad libitum*—citric acid and sugar, cream of tartar, &c. The bread must be very good, and of the finest flour, for the dysenteric cases.

Sieges.

The sanitary duties during sieges are often difficult. Water is often scarce; disposal of sewage not easy, and the usual modes of disposal of the dead cannot, perhaps, be made use of. If sewage is not washed away, and if there is no convenient plan of removing it by hand, it must be burnt. Mixing it with gunpowder may be adopted if there is no straw or other combustible material to put with it.

If food threaten to run short, the medical officer should remember how easily Dr Morgan's process of salting meat can be applied (see page 185), and in this way cattle or horses which are killed for want of forage, or are shot in action, can be preserved. For sieges, as vegetables are sure to fall short, a very ample supply of lemon-juice, and of citric acid, citrates, and cream of tartar, should be laid in, and distributed largely.

One other point should be brought to the notice of the general in command. In times of pressure, every man who can be discharged from the hospital is sent to the front. This cannot always be avoided. But when there is less pressure, the men should go from the rear hospitals to a depôt, and while there should still be considered under medical treatment, so that they may not too soon be subjected to the hardships of war. They should, in fact, be subjected again to a sort of training, as if they were just entering on the war. If this is not done, a number of sickly or half-cured men get into the ranks, who may break down in a moment of emergency, and cause great difficulty to the general in command. Some officers think that a man should either be in hospital or at his full duty; this seems to me a misapprehension both of the facts and of the best way of meeting them. To transfer a man just cured, from the comforts of an hospital at once to the front, is to run great danger. A depôt, which should be a sort of convalescent hospital, though not under that term, is the proper place to thoroughly strengthen the man just recovered for the arduous work before him.

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